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Beetle

MOLDING MATERIALS

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(1940)

AMERICAN CYANAMID COMPANY
BEETLE PRODUCTS DIVISION
30 ROCKEFELLER PLAZA
NEW YORK, N. Y.

"Beetle — The Plastic that's *all color — in all colors*" is the material described in this booklet. Reproduced on this page are but a few hundred of the thousands of colors that can be obtained in this versatile plastic. The importance of color — in industrial design, as a sales-stimulant, and for display value — is more fully accepted than ever before. Beetle, combining brilliance of color with permanence of color, provides manufacturer and designer with a new material — a new way to product improvement and increased sales appeal — frequently at lower cost.

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INTRODUCTION

● This booklet, entitled "Beetle," is issued by the Beetle Products Division of the American Cyanamid Company to bring up to date pertinent information regarding urea-formaldehyde molding compounds sold under its trade name. It is of importance to note, at the outset, that the plastics industry is not static and that data contained here will be subject to continued modification as the result of improved molding technique and improved materials.

Although our discussion will be chiefly confined to the use of urea-formaldehyde resin in the form of a molding compound, it will be of value to the reader to mention that this basic resin, because of its intrinsic properties, finds many applications in other forms.

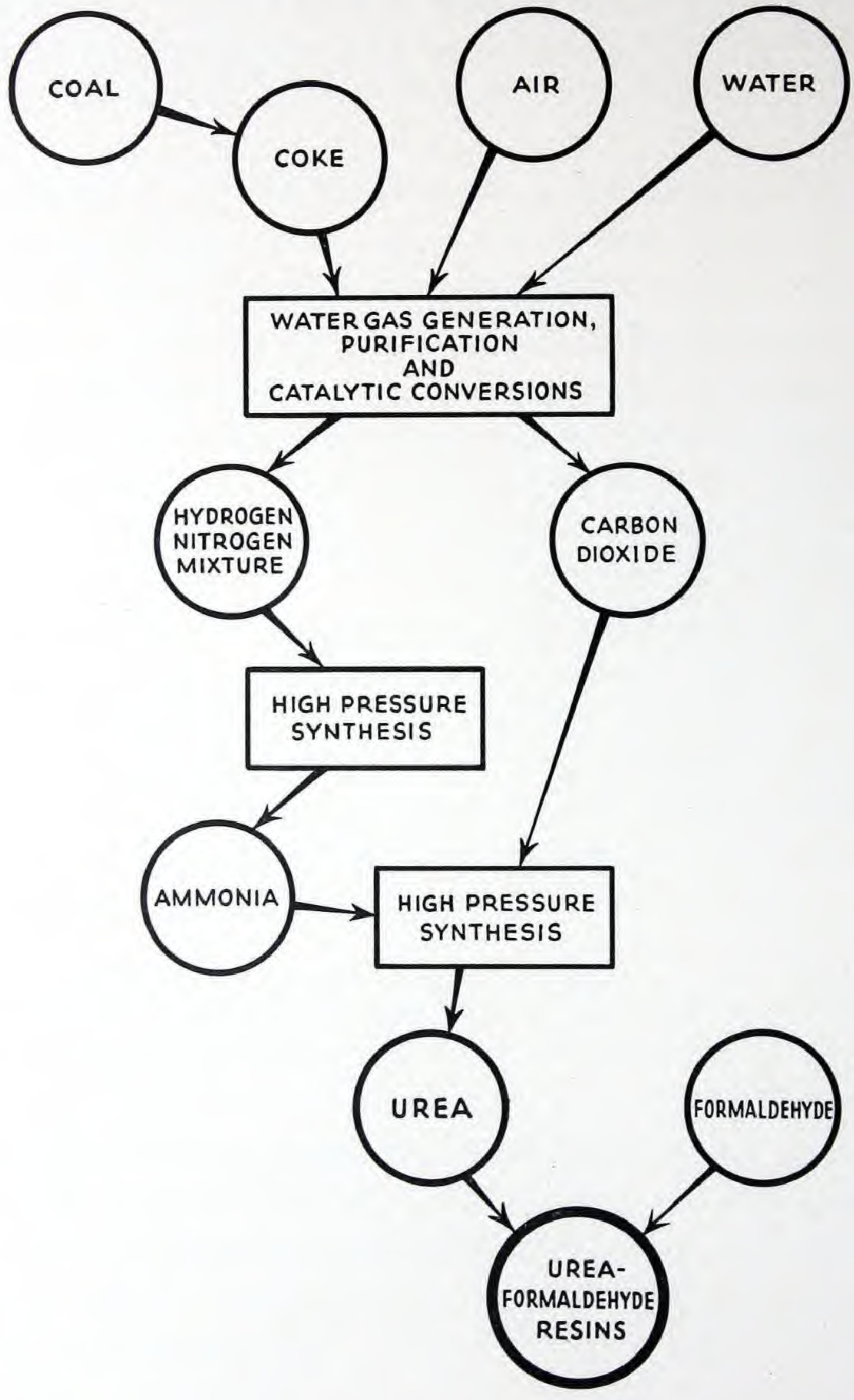
The uncured urea-formaldehyde resin is a colorless solution, fusible and partially soluble. When subjected to high temperatures, this resin undergoes a rapid chemical change and becomes insoluble, infusible, odorless, tasteless—in general, chemically inert. It is, therefore, a thermo-setting or heat-hardening resin. In the form of a solution, this resin is used for the construction of translucent or opaque laminated sheets; for the manufacture of cold-setting cements; in baking enamels; as plywood bonds and many other applications.

In combination with a finely divided alpha cellulose filler, the resin is sold as a molding compound, either in the form of a granule or a powder. Since the basic resin is colorless and the cellulose filler is a pale white, the molding compound in its natural unpigmented state will give pearl white translucent moldings. Through the addition of dyes or pigments in the manufacture of the molding compound, practically any color, either translucent or opaque, may be produced. Since the color of Beetle is due to these added coloring agents, the material is extremely color fast and as color stable as are the best dyes or pigments available.

Beetle molding compounds are molded in steel dies under the combined action of heat and pressure. The process is much the same as that used for the molding of other thermo-setting compounds.

In this book we shall give the route of our molding compound from the plant to the molder, and eventually to the consumer. We shall outline the best current molding practice, properties of finished parts and pertinent information regarding piece design and application. Naturally many problems may arise which require discussion with our technical representatives or laboratory technicians: such service is readily available to those requesting it.

FLOW CHART


COAL
COKE
AIR
WATER
WATER GAS GENERATION, PURIFICATION AND CATALYTIC CONVERSIONS
HYDROGEN NITROGEN MIXTURE
CARBON DIOXIDE
HIGH PRESSURE SYNTHESIS
AMMONIA
HIGH PRESSURE SYNTHESIS
UREA
FORMALDEHYDE
UREA-FORMALDEHYDE RESINS

BEETLE MOLDING MATERIALS

Beetle molding compounds are supplied in the forms of powder or granules, differing from each other in relative density or bulk.

Beetle Powder has a compression ratio of about 3.7 and therefore requires larger mold loading space than does the more dense material. Beetle powder produces parts having an excellent finish and parts which are slightly stronger, particularly around heavy inserts. However, because of the powder's fluffiness and bulk, difficulties may be experienced in handling and measuring mold charges; its use is generally confined to those plants having specialized equipment to handle it.

Beetle Granular, the standard form of the compound, has a compression ratio of 2.5. Although the granular form is somewhat more expensive, it affords offsetting economies in the handling, loading, and measuring operations. Granular Beetle may be tabletted, thereby further facilitating the weighing and loading of mold charges. Experienced molders are of the opinion that granular Beetle affords many economies in that it presents a form of material more easily handled in the plant.

Since Beetle compounds may be obtained in practically any translucent or opaque color, and since they are purchased because of their beauty as a finished part, Beetle is produced in "hospital clean" conditions.

This material, after being produced in an air-conditioned plant, is packed in composition drums with "Leverpak" closure. Normal container size is 200 lbs. content and measures without cover 22″ diameter by 26½″ tall, or 20½″ in diameter by 30½″ tall. Small size drums have telescoping composition tops and are available on request and on payment of a slight additional fee.

In both powder or granular forms, Beetle is supplied in many plasticities designed to meet job specifications and molding conditions. It may be safely said that throughout the molding industry, no two molds are exactly alike, nor do any two molds present the same conditions of pressure, restrictions to flow, or other variables. To meet these conditions, Beetle manufactures a wide range of materials with regard to plasticity:

1. **Very Soft**—Material designed to meet severely under-pressured molding conditions. Same rapid cure as for the hard flows.

2. **Soft**—Material designed to operate in molds slightly under-pressured.

3. **Medium Soft** and **Medium Hard**—This is customarily used as a general purpose material. It possesses a uniform flow, excellent surface appearance, rapid cure, and is very gas free. Moldings have been consistently produced in this material from small buttons to large housings.

4. **Hard**—This material is used to mold small parts such as buttons and closures, and because of its hardness it produces an unusually excellent finish.

5. **Very Hard**—This material is similar to the hard type and has been developed for over-pressured molds. Used principally for buttons.

It is important to note that the above variations are produced without sacrifice of quality or rate of cure. Soft materials require no more curing time than the harder varieties. When compared at the same temperature, the cure rates of all types are practically the same.

In addition to these standard types we also manufacture several special grades to fit particular conditions of exposure.

PROCESSING OR MOLDING BEETLE

On receipt of Beetle materials at the shop, unless they are immediately used, they should be stored in a cool, dry place. Dirt and moisture are the enemies of clean, light-colored urea molding compounds. They should be protected by adequate covering and sealing, just as carefully as the highly polished dies are protected from dirt and moisture.

Dirt means rejects; excess moisture means poor appearance and detracts from the correct flow of the product. Damp material also causes sticking to preform punches.

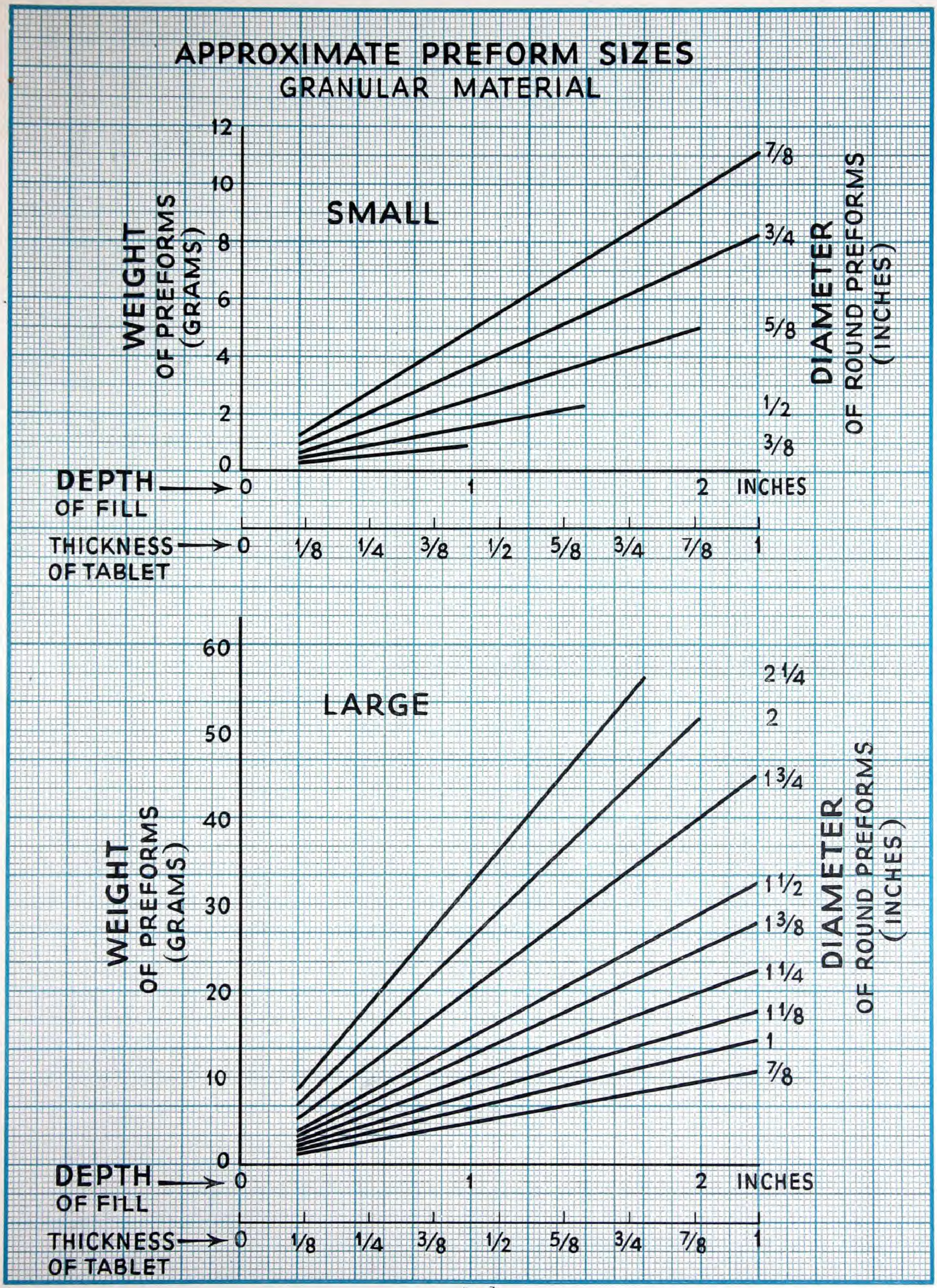
Cold storage and cold weather protect the urea compound against alteration of its flow characteristics, but for best working conditions the compound should be reasonably warm before being charged into the die. Drums of material in winter take from 24 to 48 hours to become thoroughly warmed. The time will depend on weather and storage conditions. If the material is cold it should be placed in a room where temperatures run from 80° to 100° F. for the above period. The use of hot pipes or extreme temperatures should be avoided.

Excessive moisture can best be avoided by tightly closing the drums, or by rolling them prior to use, if the outer layers have become damp.

When applications which require absolute cleanliness are to be molded, such as lighting reflectors, it would be wise to consult with a technical representative of Beetle regarding methods of handling the compound from drum to die.

PREFORMING OF UREA MOLDING MATERIALS

With all quantity production of small parts in multi-cavity dies, it is most convenient and economical to charge the mold with tablets by means of a loading board. In this way the material is automatically weighed and densified, and the minimum quantity necessary to make each piece is rapidly placed in all cavities in one motion.


APPROXIMATE PREFORM SIZES
GRANULAR MATERIAL
SMALL
WEIGHT OF PREFORMS (GRAMS)
0
2
4
6
8
10
12
DIAMETER OF ROUND PREFORMS (INCHES)
7/8
3/4
5/8
1/2
3/8
DEPTH OF FILL
0
1
2
INCHES
THICKNESS OF TABLET
0
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1
LARGE
WEIGHT OF PREFORMS (GRAMS)
0
10
20
30
40
50
60
DIAMETER OF ROUND PREFORMS (INCHES)
2 1/4
2
1 3/4
1 1/2
1 3/8
1 1/4
1 1/8
1
7/8
DEPTH OF FILL
0
1
2
INCHES
THICKNESS OF TABLET
0
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1

Beetle may be preformed in any of the standard machines that are used with phenolic compounds. There are two types, the single punch machine and the rotary. The rotary is most suitable for quantity production of round preforms up to one inch in diameter. The larger single punch machines are best suited for pills one inch in diameter to two and one-quarter inches. Although multiple punches are supplied for the large single stroke machine, it is generally found that the uniformity of tablet weight is not so good as that obtained with the smaller single punch machines or with the rotary.

Points to be noted with regard to preforming Beetle:

1. Ureas demand higher pressures than phenolics to produce similar sized pills. On a single stroke machine this will mean a smaller maximum size. For example, a certain type single stroke machine is rated to produce a three-inch diameter maximum size phenolic pill. The upper limit for ureas on this machine is between 2¼″ and 2½″. In general, rotary machines are able to handle phenolics and ureas interchangeably, so that only in the extreme sizes is it necessary to consider the excess pressure needed.

2. Since many molders make their own dies and punches, a few words should be said about their design. The most important matter here is the clearance between punches and dies. There is air between the granules and it must be permitted to escape through these clearances when the compound is compressed.

TABLE I—DIAMETRAL CLEARANCE OR DIFFERENCE IN DIAMETER BETWEEN THE PUNCH AND THE DIE

Nominal Size	Clearance—Upper Punch	Clearance—Lower Punch
¼″ diameter	0.003	0.002
½″ "	0.003	0.003
¾″ "	0.005	0.004
1″ "	0.007	0.005
1½″ "	0.010	0.007
2″ "	0.012	0.010
2½″ "	0.014	0.012

Larger clearances between punch and die cause dusting or splash of the material from the dies, and a fin will be formed at the pill edges.

Dies should be checked occasionally for wear. After considerable use their bores may become barrel shaped, causing expensive pill breakage on ejection from the die.

Handles and knobs of molded Beetle are smooth, pleasing to the touch, and colorful. Qualities of chemical inertness, moisture resistance, strength, high insulating value, and ready adaptability to design requirements, make Beetle the ideal material for handles and knobs in matching or contrasting colors.

The die should be hand polished axially to remove circular grinding streaks which impede tablet ejection. It is well to produce a slight flare outward—about .002″ increase in diameter per inch of depth—to permit easy pill ejection.

3. Among the operating details, temperature is an important factor. Since urea compounds will not produce good solid preforms at low temperatures, it is wise to allow the material to come to room temperature before preforming it.

4. Tablet machine operators often add stearate of zinc to the material to facilitate ejection of the pill. Difficulties with ejection are usually due to cold equipment, new, unlubricated die surfaces, recently cleaned dies, improperly polished parts, or damaged and scratched equipment. Whatever the reason, stearate should be used sparingly, and with constant examination of molded pieces, since there is danger of producing parts with poor surface finish or white stearate splotches. We believe it advisable, whenever possible, to adhere to the practice of dry cleaning dies rather than use of solvents.

Before preforming a drum of material, roll the drum sufficiently to obtain a uniform mixture of the particles. More uniform pill weights will result. Full drums are more difficult to mix than those having 15% to 20% of their contents removed.

PREWARMING Urea-formaldehyde material is most readily molded when warm. Because of its resistance to heat transfer, it is sometimes difficult during the short molding cycle to warm a large mass of material uniformly, and to obtain the same degree of softness or moldability throughout the charge. The closer the material can be brought to its molding temperature before being charged into the die, the better will be the piece.

On otherwise difficult jobs, prewarming will produce a piece that has not only a superior appearance but which will also be more resistant in service conditions. Since the material when hot reacts quickly and becomes unmoldable, prewarming must be carried out with close control of temperature and time of heating. Material charged into the mold at 180° F. to 190° F. gives the best results. To heat the material quickly to this temperature, it must be spread out in thin layers on a heated surface, or agitated in a heated rotating container to expose all portions for a uniform time to a heated surface. Heating surfaces should not exceed 250° F. and there should be enough surface so that not over 8 to 10 minutes is required to heat the material.

Prewarming is at best a critical operation and not recommended except in cases of difficult molding or when extra quality is required in a finished piece.

FLOW As a general rule, urea-formaldehyde materials have an optimum flow rate at which they should travel in the die, and move to fill out the piece being made. Too rapid a flow caused by too much mold pressure will not permit sufficient heat and pressure to be

Ivory is one of the most popular of Beetle colors. Because it harmonizes with virtually any color scheme it is widely used for products and appliances that find their way into the home.

transferred from mold to material, so that non-plastic portions of the charge are forced into place, leaving blisters, opaque spots, or undensified areas. Too slow a flow will permit overheating and prehardening of the charge, thus preventing complete closing of the mold.

The range of flows available in Beetle material is such that the softest types can be molded at approximately half the pressure required for the hardest types.

Because of certain conventional relations between the pressure capacity of a press and the area of a mold which can be mounted therein, two statements may be made.

1. Large, deep draw moldings which require high unit molding pressures tend to be under-pressured. Soft materials are therefore required.

2. Small, flat pieces requiring less unit pressure and having less total molded area for a given mold size tend to be over-pressured. Stiff materials are therefore required.

Between these extremes lies a wide range of conditions. There is a wide range of flow characteristics available in Beetle materials to meet these conditions without sacrifice of quality or cure time.

MOLDS Pure urea resins, unlike pure phenolic resins, do not fuse to a semi-liquid state through the application of heat alone. Urea molding compounds require both heat and pressure to cause them to flow and fill all parts of the mold; dies must therefore be designed to insure the even application of pressure and heat over the entire area of the part.

Beetle may be molded in either a flash or semi-positive type mold, depending on the shape of the piece required and the quality of product desired.

The flash type mold is best suited to produce small pieces of little or no draw, such as buttons or closures. To secure the necessary density in pieces formed in such a die, it is suggested that pills or preforms be used. Sometimes with pieces having complicated shapes or variations in sections it is necessary to make the mold slightly semi-positive.

The flash mold is not suited to produce pieces having a heavy cross section, such as knobs and gear shift balls, or parts requiring a long draw, such as tumblers.

The semi-positive mold is best suited to fabricate ureas, because it applies an even, positive pressure on the compound throughout its flow. Parts having a long flow or draw, such as tumblers, radio cabinets, or clock cases, or parts having a thick cross section, should be molded in such dies.

The use of a semi-positive die will result in a saving of raw material, since the cavity is practically closed and will not permit much of the compound to escape as flash.

Molds should be designed so that all surfaces of the die are approximately the same distance from the source of heat. The added expense of coring the mold will be offset

to a great degree by the faster production of better and more uniform parts. Differentials in cure at various localities of a large piece resulting from poor heat distribution in the die can lead to a differential in shrinkage which in turn may lead to cracking.

In order to maintain the proper mold temperature it is vital to remove the condensed steam as rapidly as possible. This requires a well-made, reliable type of steam trap with strainer.

Sample molds are usually heated by conduction and are sometimes cheaply constructed. The frequent removal of this die from the press for unloading purposes results in a fluctuation of the mold temperature. Care should be exercised to bring the die back to correct molding temperatures, if the production of poor pieces is to be avoided. The calibre of pieces produced from such a mold is not necessarily indicative of what may be produced from a permanent steam channeled die.

THE MOLDING OF BEETLE

TEMPERATURE Beetle may be molded at temperatures as low as 275° F. and as high as 340° F. Below 275° F. parts appear to be blistered, except after an extremely long cure. Above 340° F. parts may burn and whiten. The entire process of carrying molding powder through its plastic state into a hard finished piece is accelerated by the higher mold temperatures.

Ordinarily the highest mold temperatures which permit the material to remain in its plastic state long enough for complete closing, and breathing if necessary, are the most economical to use. Lower temperatures produce parts with a better finish and tend to reduce flow marks.

Small parts, where the bulk of material to be heated is small and the flow short, are generally run at high temperatures.

Large parts, where the material flows a great distance and therefore more time is required for mold closing, are run at the lower end of the temperature range.

MOLDING PRESSURES Molding pressures required for ureas are usually higher than those required for phenolics, particularly for long draw pieces. Buttons, closures, and similar small parts made in flash molds, can be formed at 2,000 pounds per square inch of projected area. By the latter is meant the total area of the molds, including the flash lands. If a higher finish is required a more stiffly flowing Beetle must be specified and the molding pressure raised accordingly — possibly to 3,000 pounds per square inch of projected area.

Housings, tumblers, and such parts having a long draw, require higher pressures. A rule of thumb may be used by setting 3,000 pounds per square inch of projected area as the basic molding pressure, to which should be added 700-1,000 pounds per square inch for each additional inch of vertical draw. This rule applies when standard materials of standard plasticity are used.

Pieces of long draw having a thick cross section require less pressure than do draw pieces of thin cross section.

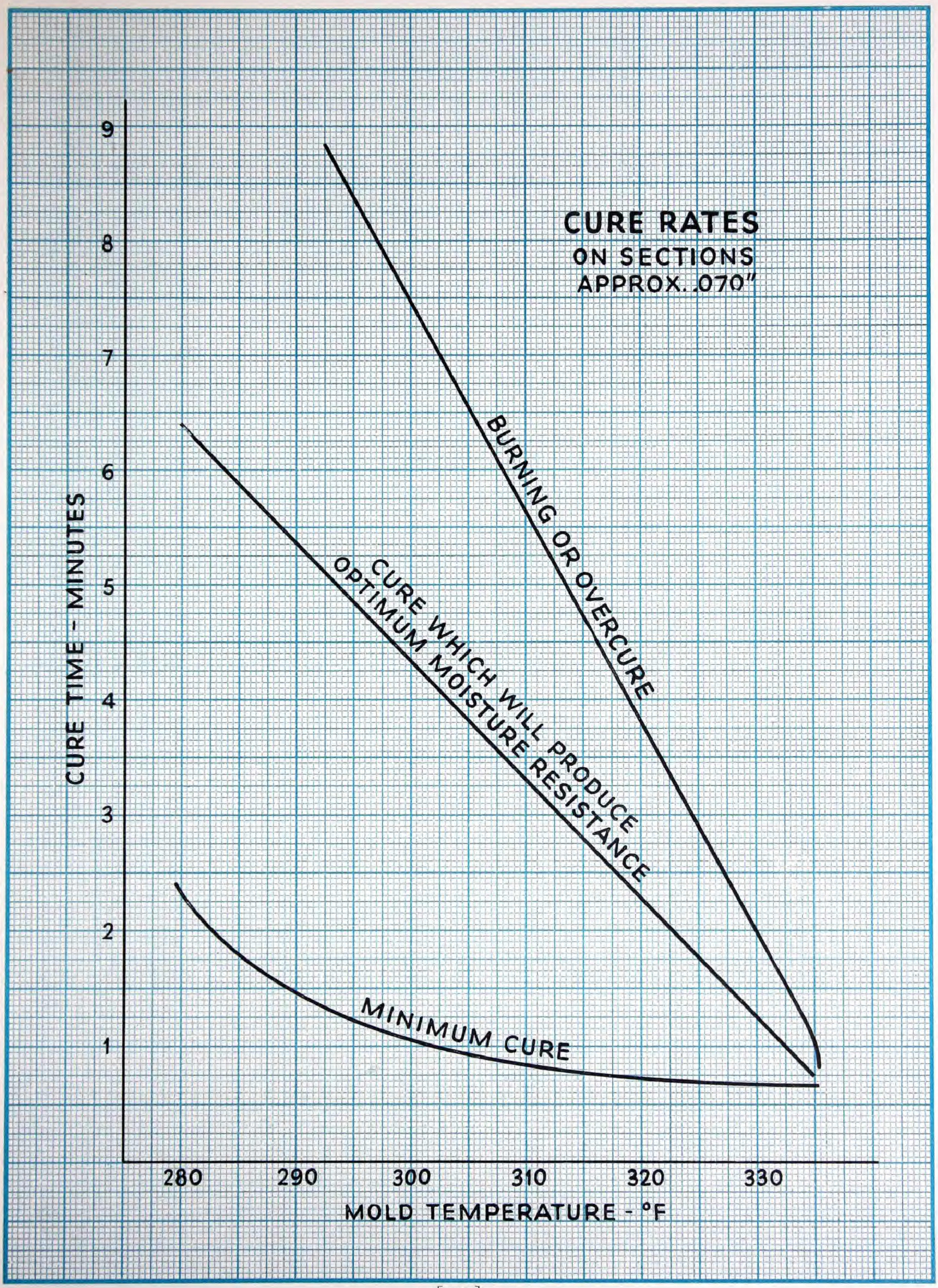
Table II below will summarize the above paragraphs.

CURE It is common knowledge that higher mold temperatures will permit shorter cures with resulting faster production rates. However, the highest permissible temperature is limited by the amount of flow required, and the general complexity of the molded piece. The relationship of heat and cure time in a given part may be seen by consulting the accompanying graph:

TABLE II—APPROXIMATE MOLDING CONDITIONS

Part	Area Projected Sq. Inches	Draw Inches	Section Thickness Inches	Number of Parts per Pound of Material	Mold Temperature Fahrenheit	Molding Pressure Tons per Cavity	Cure Time	Type of Mold
Buttons	1/4–2	—	3/32–5/32	150–1000	310–340	1/2–3	20 Secs. to 1 Min.	Flash
Closures	1/2–5	1/2–1	3/32–5/32	30–200	305–325	1–9	40 Secs. to 2 Min.	Flash or Semi-Positive
Wall Plates	15–25	—	3/32–1/8	12–20	310–320	20–35	50 Secs. to 2 Min.	Flash or Semi-Positive
Razor Housings	8–12	3/4–1	1/16–1/8	10–20	300–315	15–25	2–3 Min.	Semi-Positive
Housings Small	25–40	2–4	3/32–1/8	1–3	295–315	50–100	2–4 Min.	Semi-Positive
Housings Large	70–200	5–9	1/8–3/16	1–4 Lbs. per Piece	285–305	150–1000	2 1/2–5 Min.	Semi-Positive
Lighting Reflectors Large	200–400	3–10	5/64–7/64	1–4 Lbs. per Piece	280–300	600–1500	3–5 Min.	Semi-Positive

Buttons and closures can be molded at higher temperatures and at shorter cures because of the absence of flow and because the small mass of material may be quickly heated. Larger pieces requiring a greater flow and the uniform heating of greater masses of material require a longer cure at lower temperature.


CURE RATES
ON SECTIONS
APPROX. .070"
BURNING OR OVERCURE
CURE WHICH WILL PRODUCE
OPTIMUM MOISTURE RESISTANCE
MINIMUM CURE
CURE TIME - MINUTES
1
2
3
4
5
6
7
8
9
280
290
300
310
320
330
MOLD TEMPERATURE - °F

The first effect of cure is to transform a soft, opaque and amorphous mass into a rigid, translucent molded part. Further cure improves some of the physical properties of the piece such as its resistance to moisture and its strength. Too long a cure burns or whitens the part and may, if too long continued, damage the die surface. On parts where shrinkage is a problem, prolonged cure is not advantageous as shrinkage of the part is increased.

The test for cure of a molded part should be based on the eventual use of the part.

Housings, lighting reflectors, as well as novelty items which require no special resistance to attack of moisture or solvents, are suitably cured when parts are blister- and gas-free when removed from the mold.

Tableware, closures, buttons, and parts coming in contact with liquids or solvents, should be cured long enough so that they show no attack or loss of gloss after one-half hour immersion in boiling water.

Parts having heavy sections, such as handles or knobs, should be sawed through the thickest section and inspected for uniformity of the molding. Short cures show a white core beneath the surface. This will cause cracking of the surface and should be eliminated by a longer cure or a change in the molding cycle.

Savings can often be made by adjusting the cure to the requirements of the part being molded.

It is possible as a production control test on a molded part to measure its percentage of water absorption after 15 to 30 minutes immersion in boiling water. Parts cured to the same degree will have the same percentage of absorption, and variations in cure can be detected in this way.

The simplest mold closing cycle which will produce good parts is always preferable. The primary objective to keep in mind in molding Beetle is that the mold charge should be heated throughout before the mold is closed. Good parts are often more easily produced by a short interruption of flow after molding pressure is first applied.

In the case of long draw pieces, the mold is closed very slowly. Depending upon the weight of the charge and shape of part, the closing operation may take from thirty seconds to one minute.

If small parts are to be produced in flash molds, the procedure is to close the mold to the point where the flash has ceased flowing, then breathe the die quickly, and close for final cure. In many cases the breathing operation may be eliminated.

If difficulty is experienced from trapped air or gas, the material may be preheated 10-20 seconds with the die nearly closed. The die is then momentarily opened, and allowed to close fully. Complicated cycles are hard to reproduce uniformly and can often be simplified. Change in mold temperatures or in flow characteristics of material aid in simplification of the cycle.

Beetle housings, such as this clock case, provide protection for the instrument and insure lasting beauty. Molded in one piece, they are ideal for assembly line production methods.

Urea-formaldehyde materials in a mold flow somewhat as would be expected of a lump of ice in a mold just warm enough to melt the ice. As the mold's heat softens the outer portions of the charge in contact with the metal, the softened compound flows under pressure and exposes relatively cold, unsoftened material to the mold's heat. This process continues until the die is closed. This compound remains soft for a very limited space of time, and under continued heat quickly hardens and resists further flow.

FINISHING OPERATIONS The flash or fin on small parts such as buttons or closures may be removed by tumbling these parts in a wooden barrel. If rough finishing is required, small wooden pegs or burnishing balls are mixed with the pieces and tumbling continues for about ten minutes.

Tumbling barrels are usually driven at about 20 to 40 R.P.M. If the parts are thin and easily chipped, the speed of rotation should be kept under 30 R.P.M.

Molded urea parts coming from the die bear the polish of the mold surface. If this is to be improved upon, small parts may be tumbled with a wax polish or waxed wooden pegs from one to two hours. If an unusually high polish is required a small amount of abrasive substance may be used, and the tumbling should continue for about six hours.

If the parts are large, with thin sections, or have heavy inserts which might become broken or clogged with the polishing compound, they should be finished on a sand belt or buffing wheel.

Filing is sometimes used to remove flash, but generally as a last resort. It is sometimes necessary in the spaces formed at louvres, dial openings, and knob holes on radio cabinets. Ureas are very hard, and filing, especially with a coarse toothed file, tends to start small cracks which may extend and open up as the piece ages.

On large parts, where possible, flash should be removed by a fine sanding wheel. Care should be taken to keep the plastic cool at the point of contact.

If a mold is well polished, Beetle parts made therein will have an excellent lustrous polish. No further finishing operations are necessary except the removal of flash or fin.

CORRECTION OF MOLDING DEFECTS

Undercure—In general undercure of a molded part results in blisters or opaque spots. An odor of formaldehyde is also noticeable. The symptoms of undercure—blisters and opaque spots—may also be due to improper mold closing, and if a longer cure does not remove them, the closing of the die may be slowed down, or the mold may be breathed to remove the fault.

Overcure—Overcure is indicated by a whitened surface on the part, and if sufficiently severe, is accompanied by a fishy odor. Overcure may be corrected by reducing the mold temperature and/or reducing the cure time.

Large housings can be strong yet light in weight. Color is a part of the material itself.

No painting or polishing is necessary. The manufacturer of this scale reported his housing costs reduced 75 per cent when the Beetle model was adopted. Four molded parts provide the complete case for the delicate mechanism — simplifying the assembly job.

Flow Lines—Flow lines on a given part are frequently removed by a slower mold closing and lower mold temperatures. In extreme cases prewarming of the compound is necessary.

Low Density Areas—These areas may be due to insufficient mold charge, the result of too free flowing material, causing it to spurt out of the die, too rapid a mold close, or faulty die construction.

Water Resistance—In a given material water resistance is a function of cure. Both too long and too short a cure will produce poor water resistance. Generally the *best* results are obtained by fairly long cures at medium temperatures. Special varieties of Beetle are available where the optimum water resistance is desired. Actual immersion and weighing tests on the part in question are the best methods of determining the optimum cure for a given part.

Heavy Fins—Heavy fins on a molded part may be the result of several causes, and a remedy should be sought by checking the following factors:

1. The mold should close evenly and be properly aligned.
2. Charges of material should not be too great.
3. Mold closing time should not be prolonged more than necessary.
4. Mold temperature should not be too high.
5. Material's flow characteristics should not be too stiff.
6. Semi-positive clearances should be ample.
7. New molds may be troublesome until "broken in."

Warping—Warping of parts is best counteracted by cooling the molded parts on a form or shrink block. Only a short time is necessary for this operation and successive parts can be placed on the forms while others are molding. A shrink block will not eliminate shrinkage—it will control it.

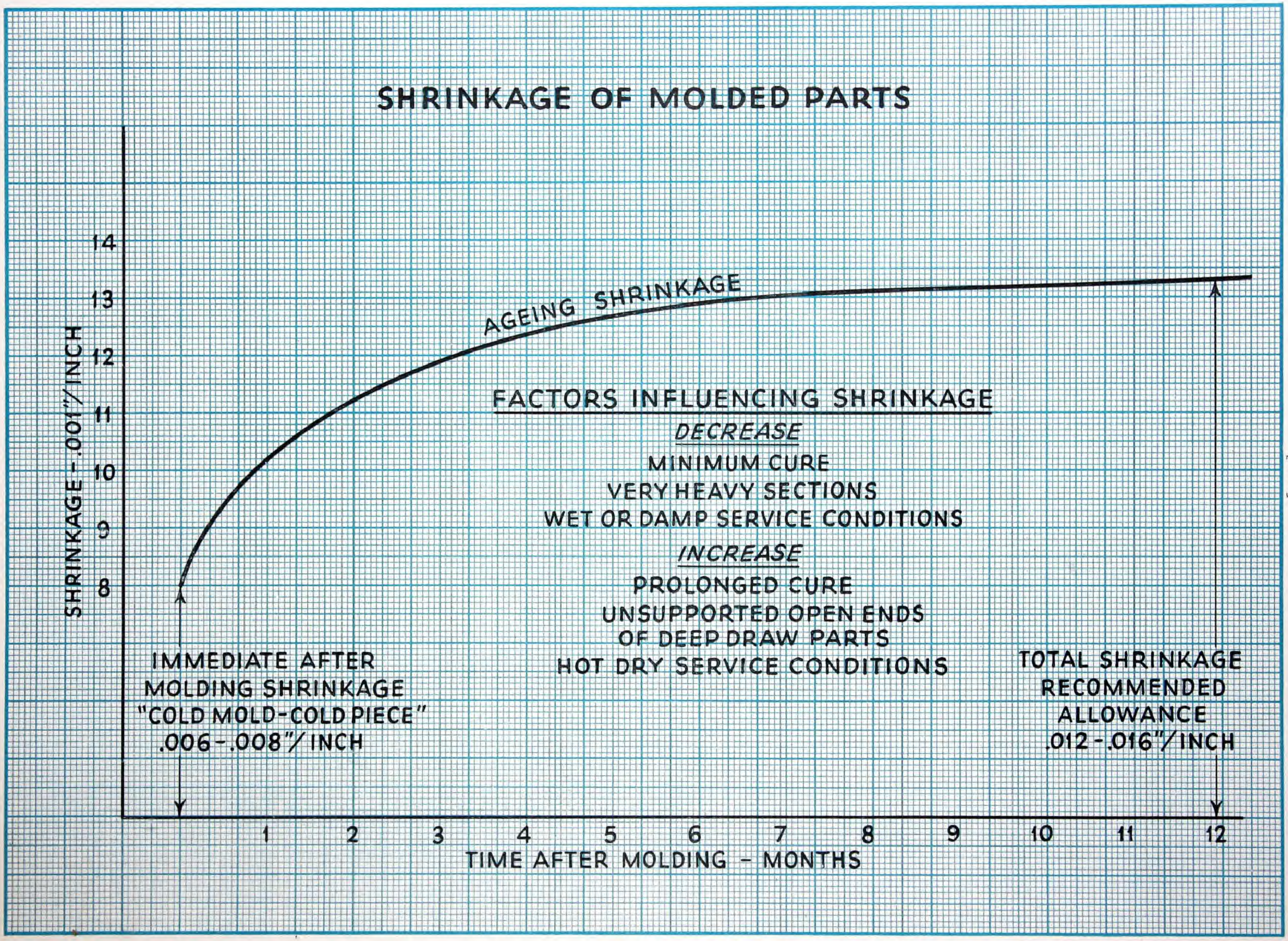
STORAGE OF FINISHED PARTS

Molded ureas respond to warm, damp weather by swelling and to a dry atmosphere by shrinking. If a molding is at all critical with regard to size, if it is on the borderline of dimensional tolerances, it should not be stored in a hot, dry room. Moldings undergo the least dimensional change and strain if they are kept at about 65-70° F. and a relative humidity of 65%.

SHRINKAGE

One of the most important factors to consider with regard to finished urea parts is the matter of dimensional change or shrinkage. In order to prevent assembly and service difficulties on molded parts where dimensional tolerances must be held, a correct allowance for shrinkage is essential.

There is an initial shrinkage of ureas which occurs immediately after a part is removed from the die. In addition, further aging shrinkage takes place over a prolonged


SHRINKAGE OF MOLDED PARTS
SHRINKAGE - .001"/INCH
8
9
10
11
12
13
14
AGEING SHRINKAGE
FACTORS INFLUENCING SHRINKAGE
DECREASE
MINIMUM CURE
VERY HEAVY SECTIONS
WET OR DAMP SERVICE CONDITIONS
INCREASE
PROLONGED CURE
UNSUPPORTED OPEN ENDS
OF DEEP DRAW PARTS
HOT DRY SERVICE CONDITIONS
IMMEDIATE AFTER
MOLDING SHRINKAGE
"COLD MOLD-COLD PIECE"
.006-.008"/INCH
TOTAL SHRINKAGE
RECOMMENDED
ALLOWANCE
.012-.016"/INCH
1
2
3
4
5
6
7
8
9
10
11
12
TIME AFTER MOLDING - MONTHS

period of time, and is greater in hot, dry atmospheres than in moist, cool air. If the moisture in the air is sufficiently great, the piece may swell.

Initial shrinkage from cold mold size to cold finished molding runs .006-.008" per inch. After-shrinkage or aging shrinkage may run from half to once again this amount, so that where design permits, the full .012-.016" per inch should be allowed.

Summarized in the graph are the shrinkage data for Beetle molding materials.

PROPERTIES OF BEETLE MOLDING MATERIALS

GRANULAR	Size of Particle—16 mesh* Apparent Density—.55-.60 Specific Volume—45-55 cubic inches to the pound Compression Ratio—2.5 Preform Possibilities—Excellent
POWDER	Size of Particle—200-300 mesh Apparent Density—.4 Specific Volume—65-70 cubic inches to the pound Compression Ratio—3.7 Preforming Possibilities—Poor

PROPERTIES OF FINISHED PARTS

Physical Properties —

Specific Gravity—	1.45-1.50
Weight per Cubic Inch—	0.85-0.89 oz. (24-25 grams)
Flexural Strength— (ASTM D-48-34T) 5"x 1/2"x 1/2" bar, supports 4" apart, loaded in center	10,000-13,000 pounds per sq. in.
Flexural Strength, Dynstat 1.5 x 1.0 x 0.2 Cm.	11,000-15,000 lbs. per sq. in.
Compressive Strength— (ASTM D-48-33)	20,000-24,000 lbs. per sq. in.
Tensile Strength— (ASTM D-48-33)	5,500- 7,000 lbs. per sq. in.
Impact Strength, Dynstat 1.5 x 1.0 x 0.2 Cm.	10-12 cm. kgs. per sq. cm.
Impact Strength, Charpy Unnotched bar 5"x 1/2"x 1/2"	1.2-1.4 ft. lbs.

*A range of particle sizes is available to give an aggregate with optimum flow in feed hoppers, and also the best surface finish on the molded piece. Maximum particle size 16 mesh U. S. Std.

The smooth, wear-resistant surface of Beetle is ideal for products which must stand the abuse of constant handling in use. The color is *in* the material itself—there is no surface coating to chip or wear off.

Rockwell Hardness— (ASTM D-229-34T) 1/4″ ball—100 kg. load	78.9
Distortion Under Heat— (ASTM D-48-39)	130° C.-140° C.
Coefficient of Heat Expansion—	0.00001-0.00002 inch per inch per degree F. These values apply for temperatures from 100° F. and lower. At higher temperatures a slight shrinkage occurs which will reduce the apparent expansion. This must not be confused with mold shrinkage.
Burning Rate—	Very slow
Machining Properties—	Fair
Softening Point—	None

Water Absorption—
Piece .050″ thick
Total immersion 24 hours at 25° C. 1 to 3% by weight

Weather Resistance—	Fair
Cold Flow—	None
Operating Temperature Maximum—	170° F.
Color—	Any color from a translucent white

Electrical Properties —

Dielectric Strength, Step-by-Step Method (ASTM D-149-36T)

Thickness of section 0.080″	
25° C. room temperature	300-385 volts per mil.
100° C. (212° F.) under oil	100-140 volts per mil.

Volume Resistivity—Megohm—Cm.—(Electrical Testing Laboratory Report No. 138291)—

After 48 hours at 60% relative humidity	10^6–10^7
After 24 hours immersion in water	10^5–10^6

Surface Resistivity—Megohms—(Electrical Testing Laboratory Report No. 138291)—

After 48 hours at 60% relative humidity	3-10 x 10^6
After 48 hours immersion in water	0.02-0.11 x 10^6

Power Factor and Dielectric Constant—

	Power Factor	Dielectric Constant
Low Frequency—60 cycles—		
Temperature 25° C. (77° F.)	4.0-4.9	7.6-8.2
Temperature 60° C. (140° F.)	8.0-9.0	8.0-9.2
High Frequency—10^6 cycles—		
After 48 hours at room temperature (75° F.) 60% R.H.	2.65-2.65	6.6-6.6
After 96 hours in water at 75° F.	6.24-7.55	10.8-11.6
Arc Resistance (ASTM D-495-38T)—	120-180 seconds	

Chemical Properties —

1. Insoluble in water, but slightly absorbs water and water solutions.
2. Attacked by strong acids and alkalis.
3. Unaffected by alcohol, acetone, hydrocarbon solvents, oils and greases.
4. Odorless and tasteless.

(Except where noted tests were conducted by the American Cyanamid Company Laboratories, Stamford, Conn.)

Translucent Beetle in white or brilliant color is finding increasing use in lighting applications of all types because of its light weight, strength, and "shatter-resistance." The illuminated cross of this window display is an excellent example of the utility of Beetle. Molded in one piece — production and handling costs are low.

APPLICATIONS OF MOLDED BEETLE

The enumeration below of applications for Beetle covers outstanding uses and will not attempt to mention all possibilities for the compound. New applications are occurring daily and may join those herein mentioned.

1. **Buttons**—Molded Beetle is used for buttons, decorative slides, clasps and buckles. The outstanding use in this field is for buttons on shirts, underwear, and pajamas.

2. **Closures**—Because of its brilliant colors and inertness Beetle is widely used for bottle caps and jar closures.

3. **Housings**—Beetle is used for radio cabinets, electric razor housings, clock cases, timer housings and a multitude of other smaller applications where color and permanence of finish are essential.

4. **Tableware**—Because of its light weight and strength Beetle is used in the form of tableware for yachts, trailers, airplanes, and picnic sets.

5. **Containers**—Molded Beetle is used for jewelry packages, cosmetic containers, cake boxes, cigarette and razor containers and a great variety of such applications where color stability, inertness, strength and resistance to wear are of importance.

6. **Stove Handles**—Colorful handles of Beetle decorate most kitchen stoves. Permanence of finish, color, and lack of heat conductivity are of importance.

7. **Wiring Devices**—Beetle is an excellent electrical insulator. It provides insulation, and color to blend with interior decorations.

8. **Lighting**—Beetle is used for lighting reflectors on portable lamps, for ceiling reflectors, automobile dome lenses, illuminated signs and displays. Beetle is eminently suitable for such applications for the following reasons:

   A. It is available in practically any translucent color.
      (1) The color and degree of light transmitted and reflected can be controlled and can be attuned to meet many different conditions.

   B. Beetle reflectors are extremely lightweight and durable.
      (1) A reflector molded of Beetle weighs about ⅓ as much as a similar reflector made of glass.
      (2) It is strong and shatter-resistant. Reflectors as big as 24″ in diameter are now being produced in Beetle.

   C. It provides efficient lighting and illumination which is easy on the eyes. Reflectors with an efficiency of 87% are produced from Beetle material, and have a surface brightness of less than 2-candle power per square inch.

   D. The light transmitted through Beetle is very diffused.

   E. It is a safe and economical material for reflectors. Because of its light weight and strength, shipping costs and packaging costs are reduced. Cleaning and maintenance charges will be lower.

Left and above are two Beetle Safety Reflectors — the 8″ and 9⅜″ sizes — approved for use with I.E.S. lamps. Below is a large molded Beetle bowl for commercial installation.

Above is the 6″ Beetle Safety Reflector for pin-up type portable lamps. Below is an adapter type bowl for modernizing existing overhead outlets.

We believe that the design and construction of Beetle lighting units require a study of special properties of the material, such as heat resistance, light transmission and reflection, color, life expectancy, etc. Our technical representatives will be glad to assist in the analysis of these problems.

DESIGN OF MOLDED BEETLE PARTS

We strongly advise that the buyer of molded parts, or the molder, construct a model of any new part before starting the die. This model should be analyzed in the light of good molding practice, service conditions after molding, and the physical and chemical properties of the plastic. The raw material supplier is always ready to lend assistance in this analysis.

Beetle in the mold becomes plastic by virtue of applied heat and pressure. As it flows throughout the mold, it is slowly stiffening and will eventually set. Perhaps the simplest part to mold is a shallow bowl of uniform wall thickness. Here there are no impediments to flow and if the die is correctly charged, the material will flow to the flash ports, set, and be ejected as a good part.

Since the basic molding process involves the shaping of a part by pressure applied in one axial direction, and the ejection of the piece along this same axis, the principles of metal casting design should be closely followed in the design of dies.

The most important fact to remember in designing molded parts is that walls or cross sections must be kept uniform in thickness. Non-uniform wall thickness leads to differentials in shrinkage, in flow and cure. The strains set up by such differentials will cause cracking and warping.

Side walls of pieces which form nearly a right angle with the base should be given a slight flare of one to two degrees for easy removal of the plunger and the molded part from the die. Right angles should be avoided. Such angles trap material or impede the material's flow. All corners or angles should have a small radius or fillet to permit the material to flow evenly throughout the piece.

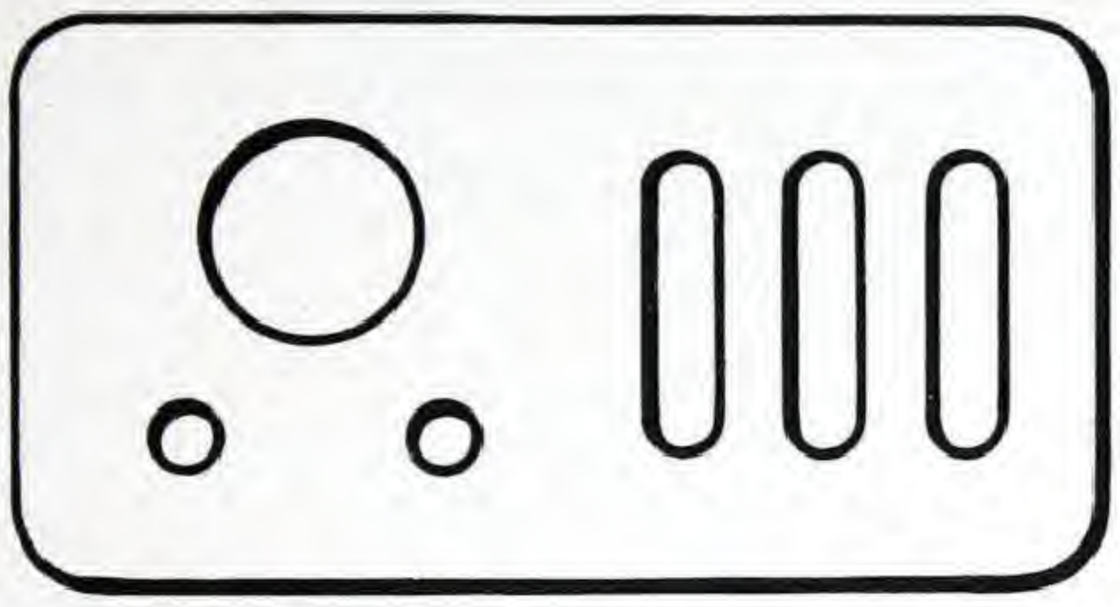
Excessively thick walled sections should be avoided. Such sections are expensive and difficult to cure thoroughly. Core out the piece if possible.

If a flat section is to be molded having slots or openings in it, formed by baffles in the die, care must be taken to see that the material can flow at the same rate into all parts of the die and arrive in all localities at a uniform plasticity. If material is squirted through narrow slots because of uneven mold loading or non-uniform location of slots or baffles, it may not knit or bond properly.

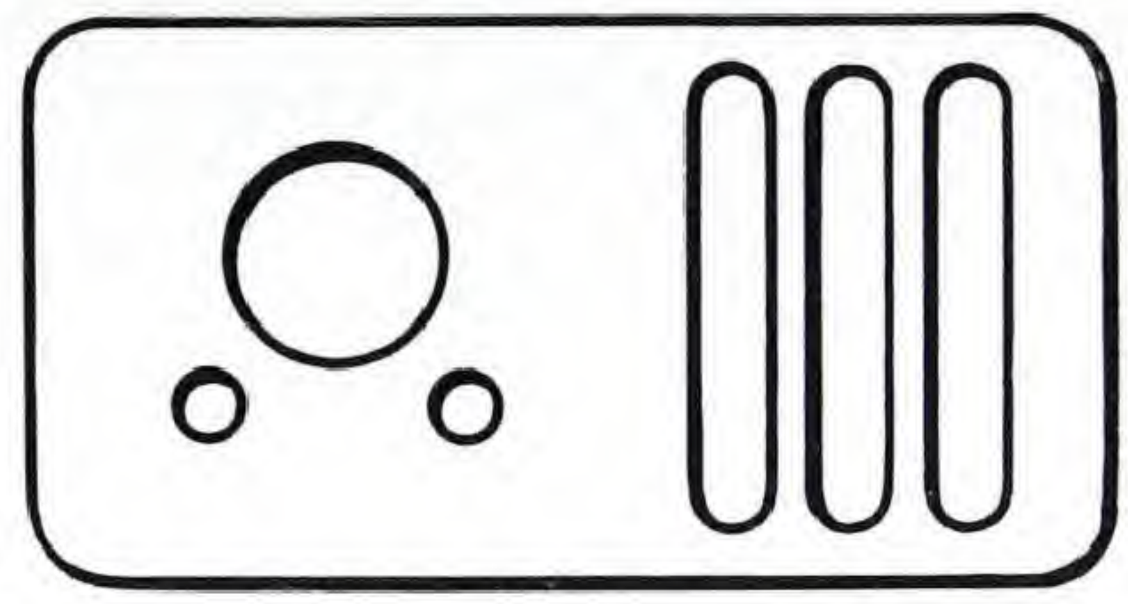
A. Open—Beetle granules in bottom of die.

B. Partially closed—Flow and cure begin.

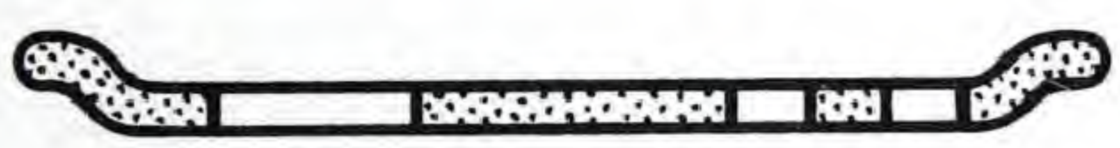
C. Closed—Material fills all parts of die.



Good Practice—Openings well spaced and rounded. Even flow is assured.



Poor Practice—Openings unbalanced allowing greater flow toward left.



Even Wall Thickness—Smooth, unimpeded flow and even cure.

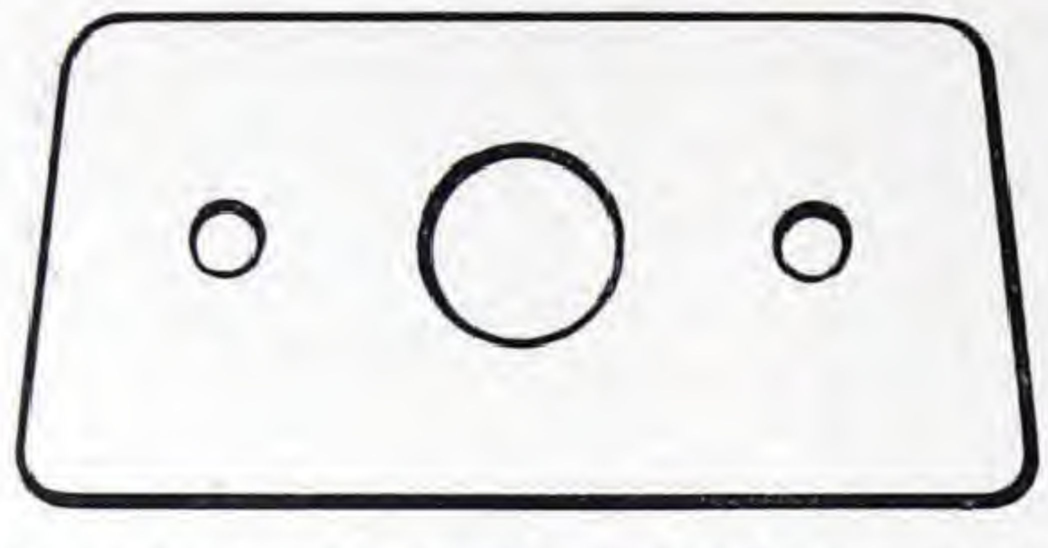
Uneven Wall Thickness—Impedes flow, causes uneven rate of cure.

When material flows from the horizontal to the vertical, to form side walls, it must be permitted to flow uniformly. The angle at which the material leaves the horizontal and enters the vertical should be given an ample radius. Pressure should be constantly on the material, and the design should be such that the compound flows to the top of the die in a uniformly plastic condition. Heavy sections at the top of the die should be avoided.

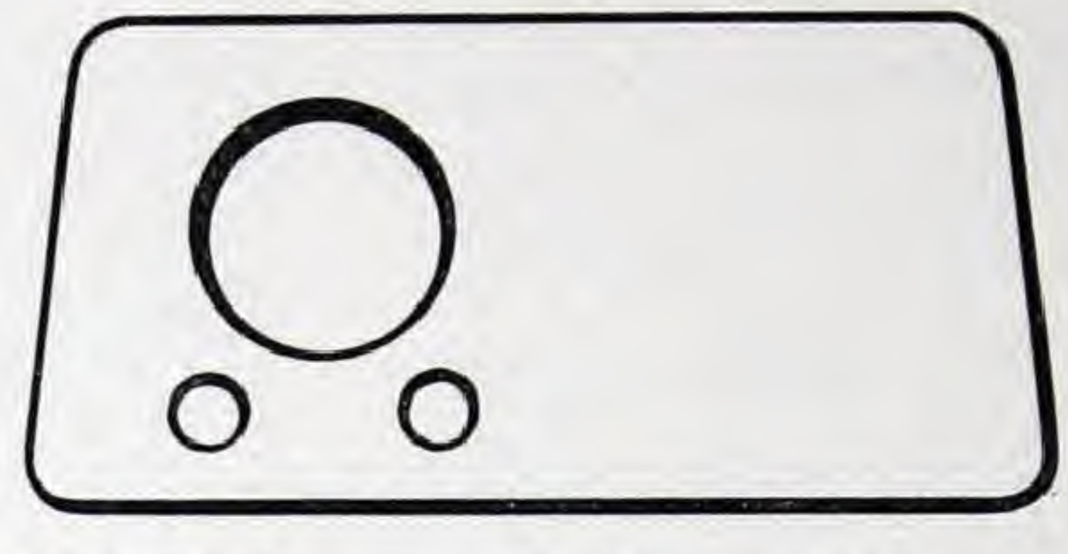
If baffles occur in the side wall to form dial openings, slots, or holes, they should be rounded, uniformly spaced, and placed as near the bottom of the die as possible. Such baffles should be quite far from each other to permit the passage of material around them. The ribs of radio grills should be as short as possible and uniform in thickness.

Drilling of large holes in the lighter sections of molded pieces is not advised. Drilling may start small cracks which will spread as the material ages.

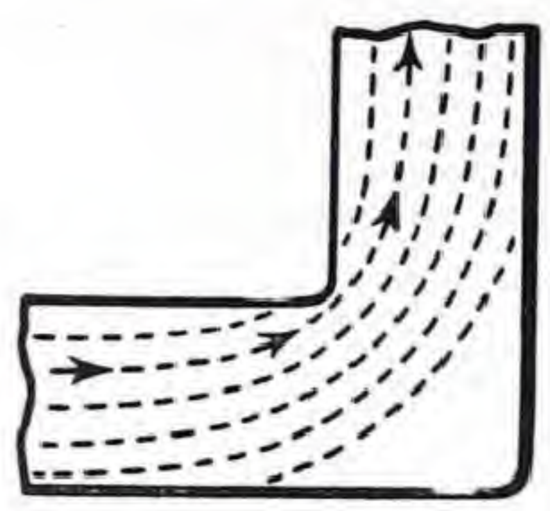
If a radio cabinet is being designed it would be well to locate the tubes of the set as



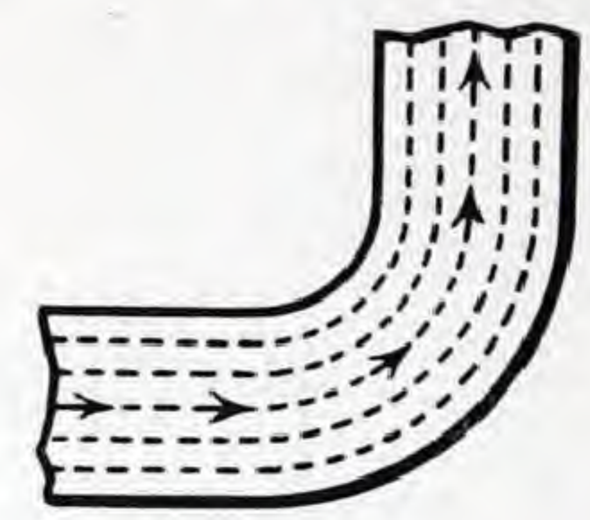
Open back cabinets—the material flows evenly into vertical for formation of walls.



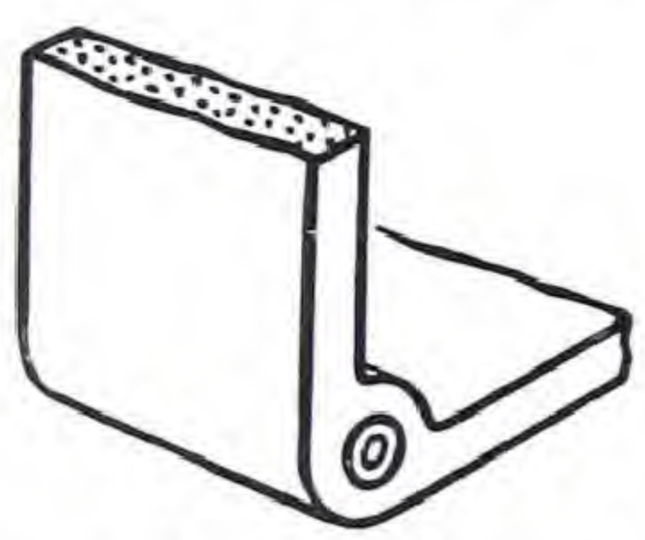
Material flows unevenly into vertical sections or walls, greater flow occurring at right.



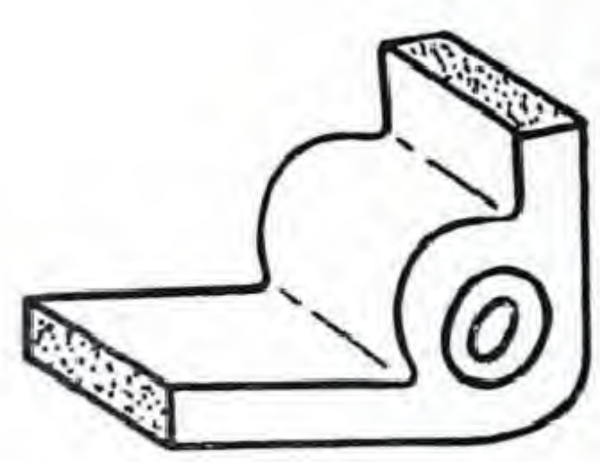
Poor Construction—Material does not fill out square corners.



Good Construction — Corner flow presents no difficulty if rounded.



Lugs or ribs should be located in corners as they may show flow lines if in a flat section.



Ample material should surround metal screw inserts, etc.

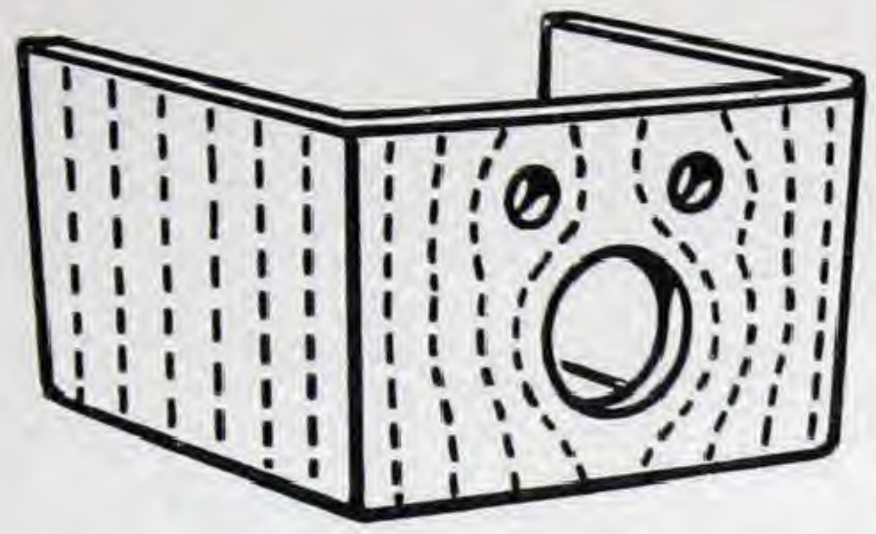
If lug must be located in flat area, fluting on outside will tend to conceal any flow lines.

far away as possible from the Beetle surface. If they must be near the plastic, the material should be ventilated or painted with a heat reflecting paint.

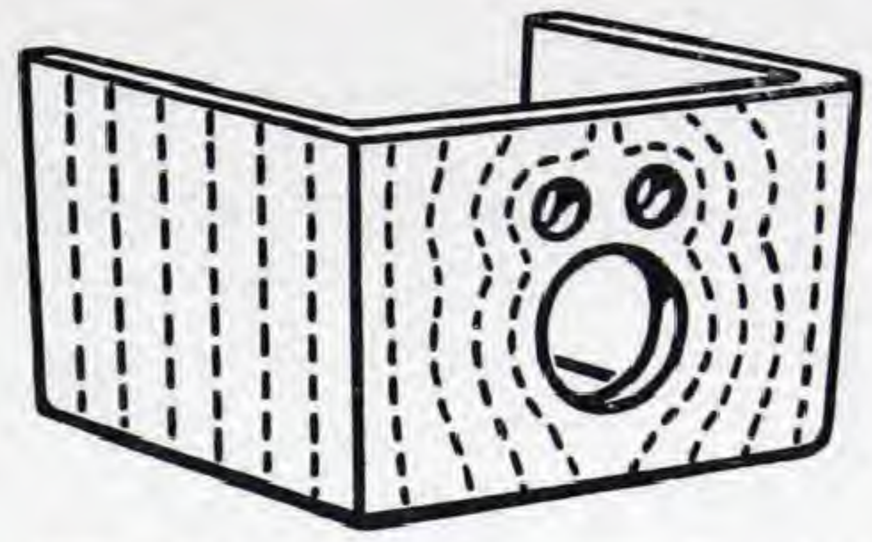
Bosses should be located in the corners of molded pieces. Here there is an abundance of material during the molding operation, and flow lines or shadows which may occur from a thick cross section in a translucent material will be avoided. If bosses are located in the side walls, some decorative fluting may be placed on the outer face to conceal the shadow or flow lines.

Always locate flash lines where they will not be seen, preferably along a decorative line or edge.

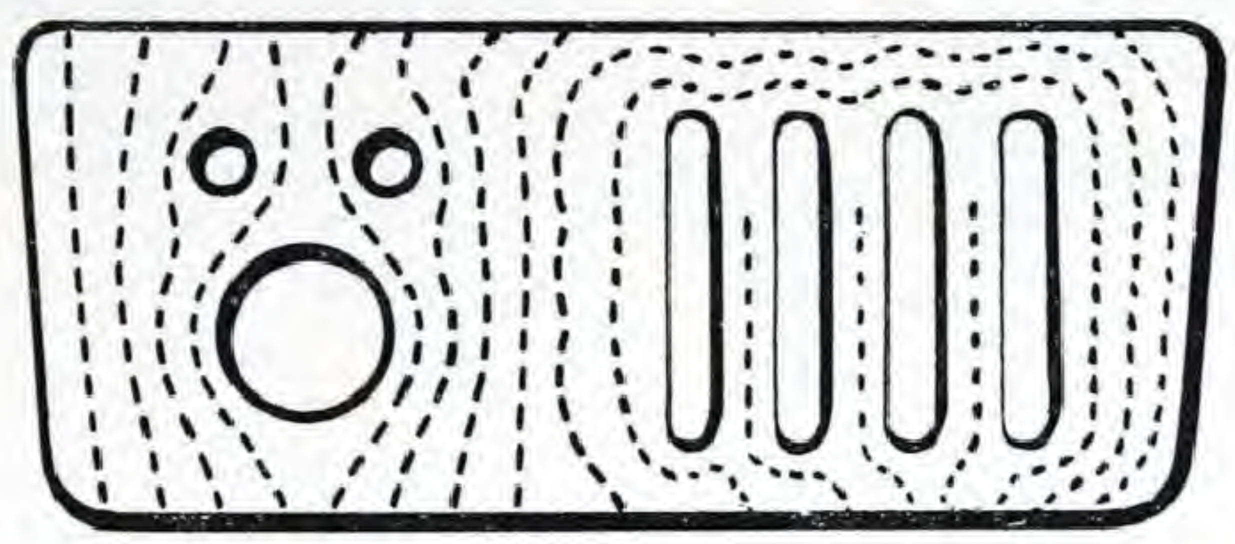
Molded parts should be permitted to alter their dimensions in varying atmospheric conditions. If ureas are held rigidly in place, or are bolted to another material which has a different rate of dimensional change, they may crack.



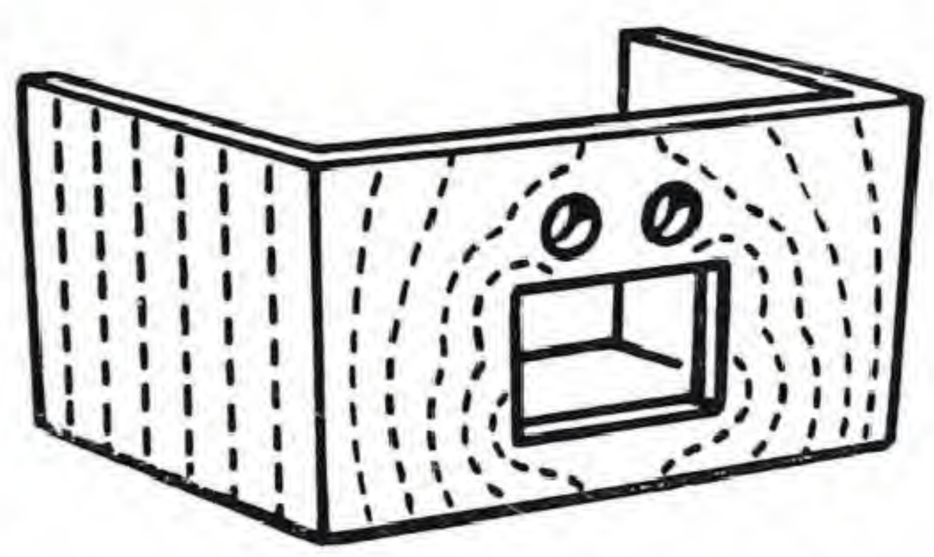
Material flows evenly around widely spaced openings.



Openings placed too close together leave pocket or trap.



Material takes path of least resistance, flowing rapidly into unobstructed areas, slowly through small channels, arriving in uneven state of cure at common finish of flow.



Square openings tend to further deflect or impede even flow.

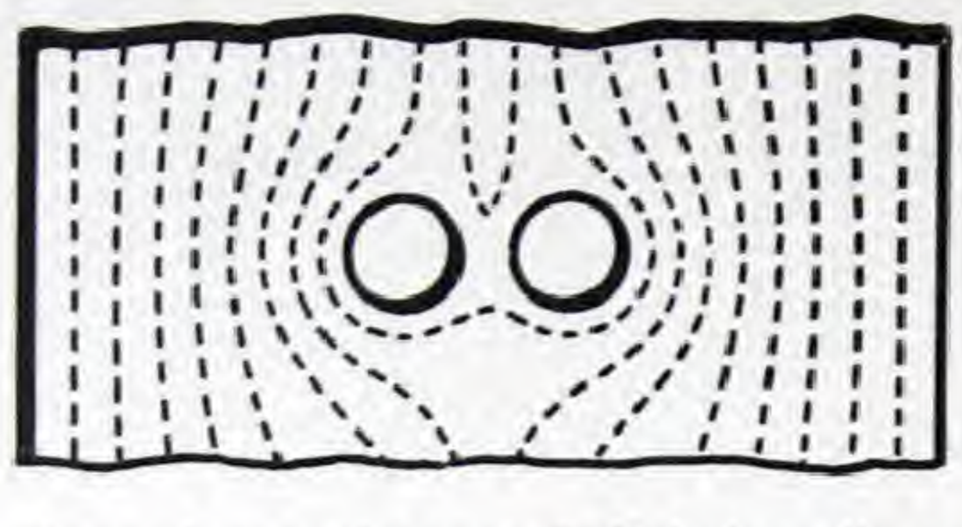
Decorations, lettering, etc. should be raised in the molded piece. Depressed designs mean raised designs cut on the steel; this work is expensive.

Molded holes should have a ratio of length to diameter of not more than 2½ to 1 if possible. This will prevent binding or breakage of mold pins.

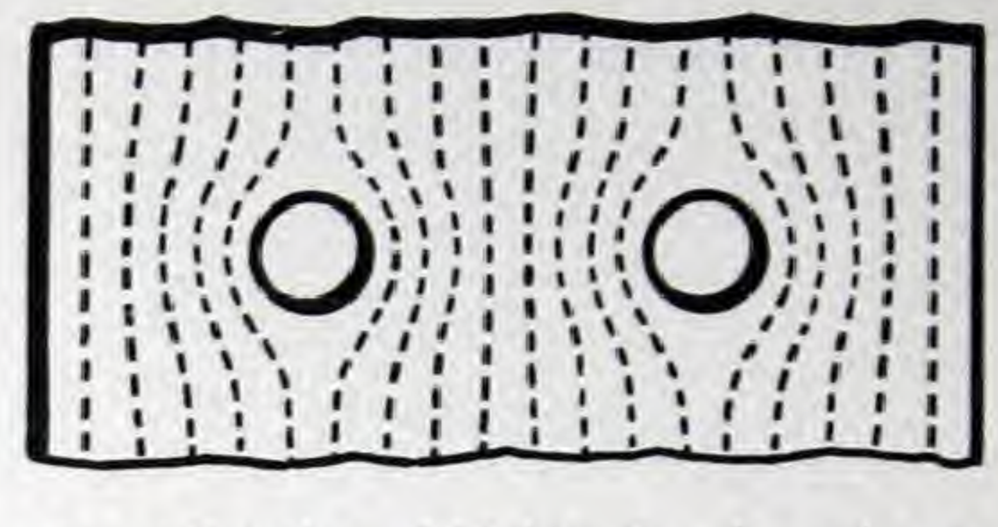
Metal inserts may be used but care must be taken to see that they are strong and thoroughly anchored in the die. The insert should occur where there is an abundance of material in the parts. Thin plastic walls around an insert will crack.

Inserts should be heavily knurled and should protrude beyond the molded surface. If the insert is flush with the piece, material may flow into it or around it, causing an expensive cleaning operation.

Hexagonal inserts are apt to cause trouble and expense. A hexagonal hole is expen-



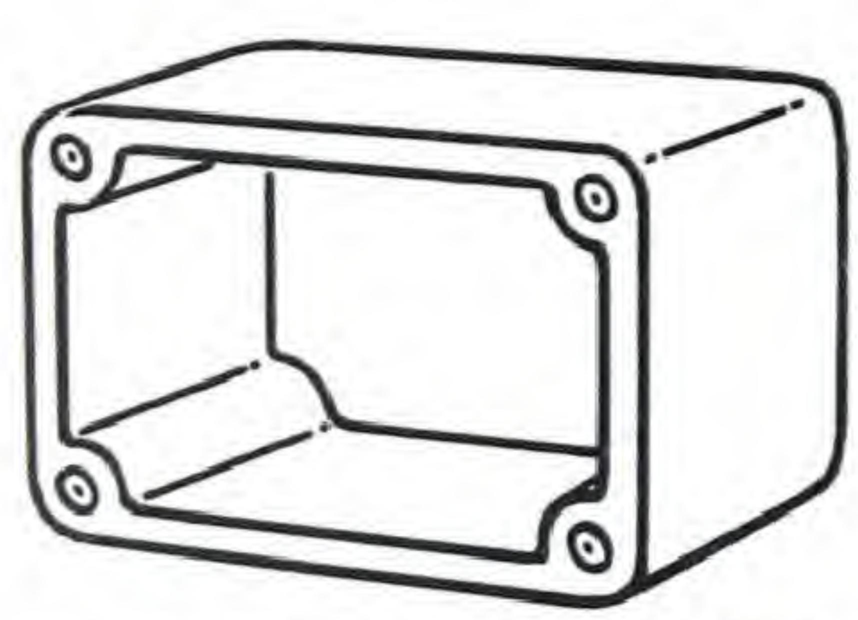
Spaced too close or "off balance" may cause a retarded and unbalanced flow.



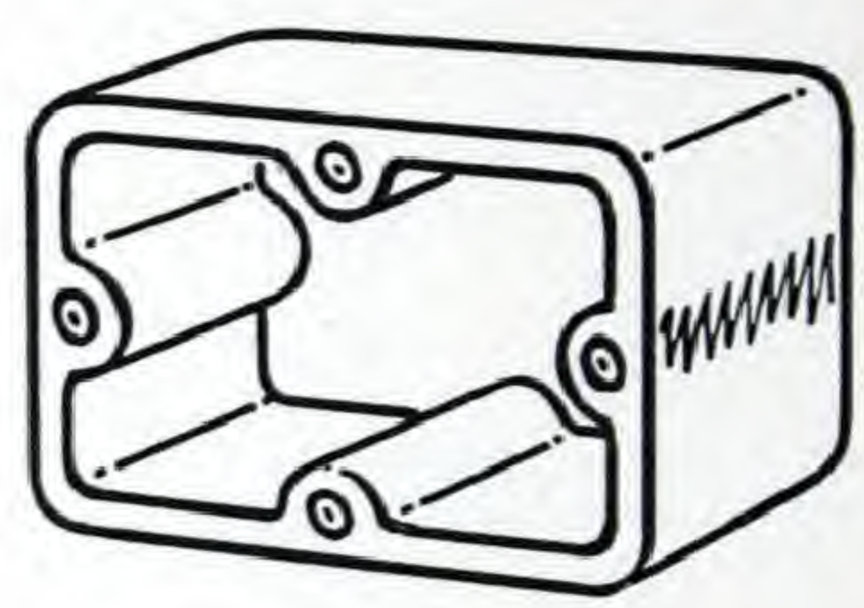
Proper Spacing of Holes—Ample and even flow round *and* between.

Avoid thin wall around openings as it may cure too rapidly, shrink unevenly.

Even or nearly even wall thickness is greatly desired.



Lugs in corners where natural abundance of material occurs.



This may cause flow lines or shadows due to uneven cross section.

sive to cut in the die, and the hexagonal insert presents sharp corners which may cause the plastic to crack.

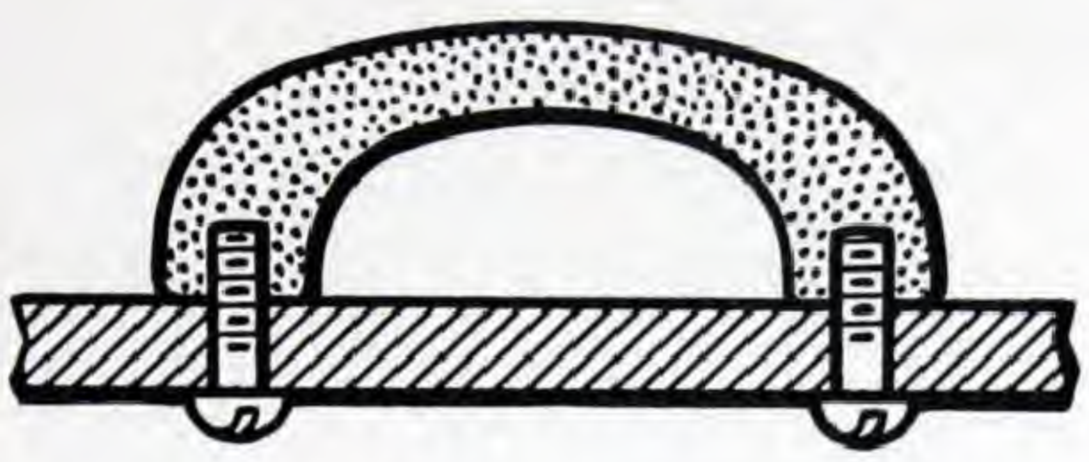
Don't call for blind holes or inserts in the side wall of a piece where the depth of the hole or the length of the insert is greater than twice its breadth.

Frequently the trouble and expense of placing inserts in a molded piece can be avoided through the use of drive screws. Holes may be molded into the piece at no extra cost, and the assembly is made by using these screws without slowing up the operations at the press. These screws do not lend themselves to disassembly.

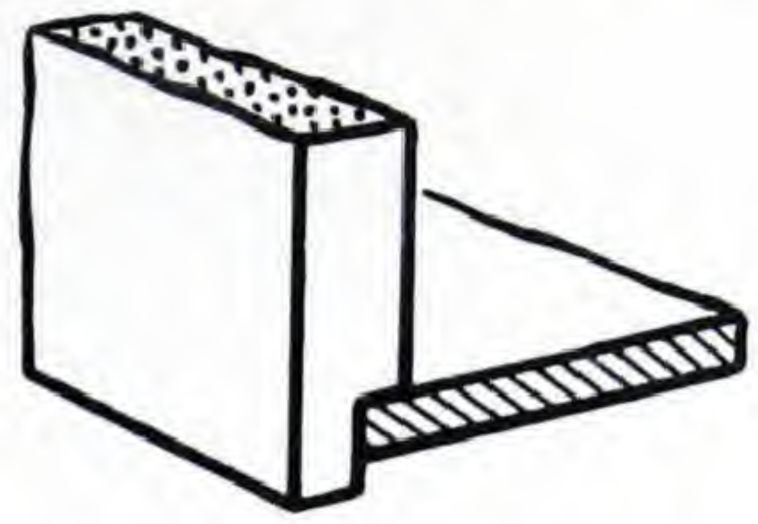
TAPPING AND DRILLING OF MOLDED BEETLE

Specific instructions cannot be given as the method of operation varies with the size and depth of hole and whether the hole is to be drilled through or is blind. Drill speeds are

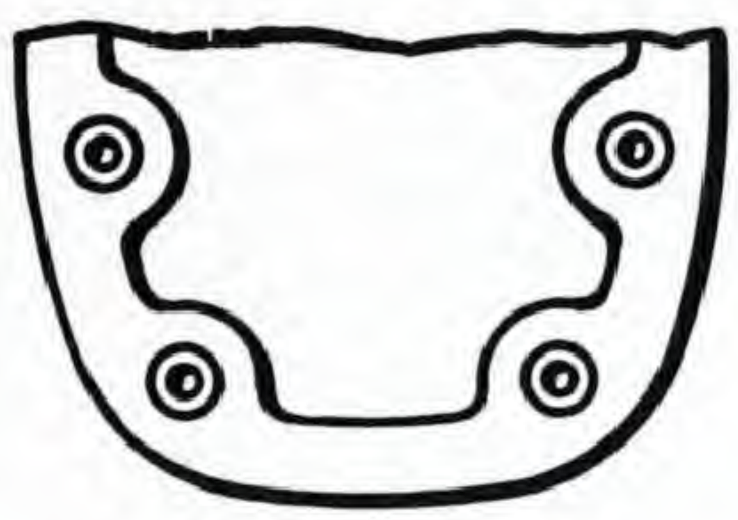
WHERE ALLOWANCE SHOULD BE MADE FOR SHRINKAGE



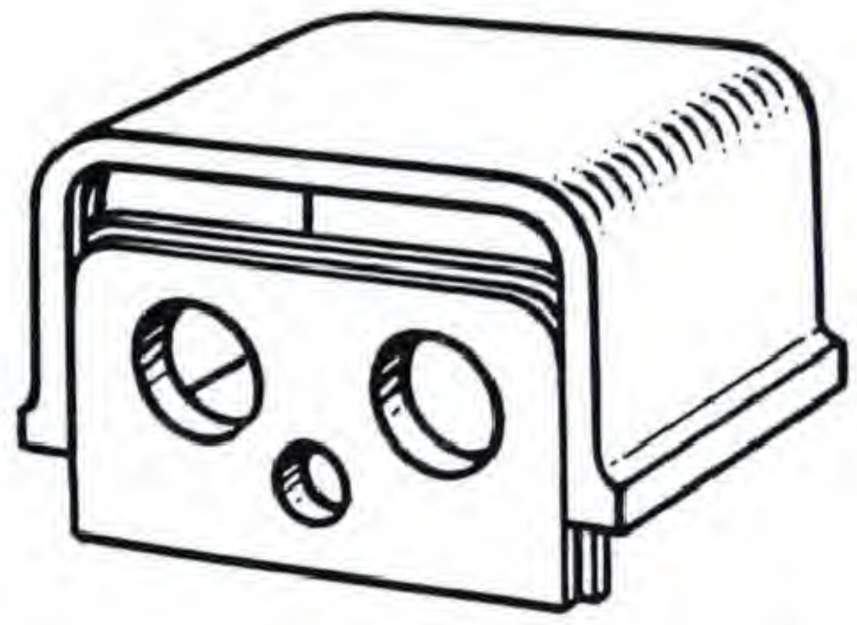
Metal frame or brace.



Joints of metal and plastic.



Dimensional changes of parts joined by metal screw inserts must also be determined.



Dimensional changes should be calculated for demountable pieces to insure ample tolerances.

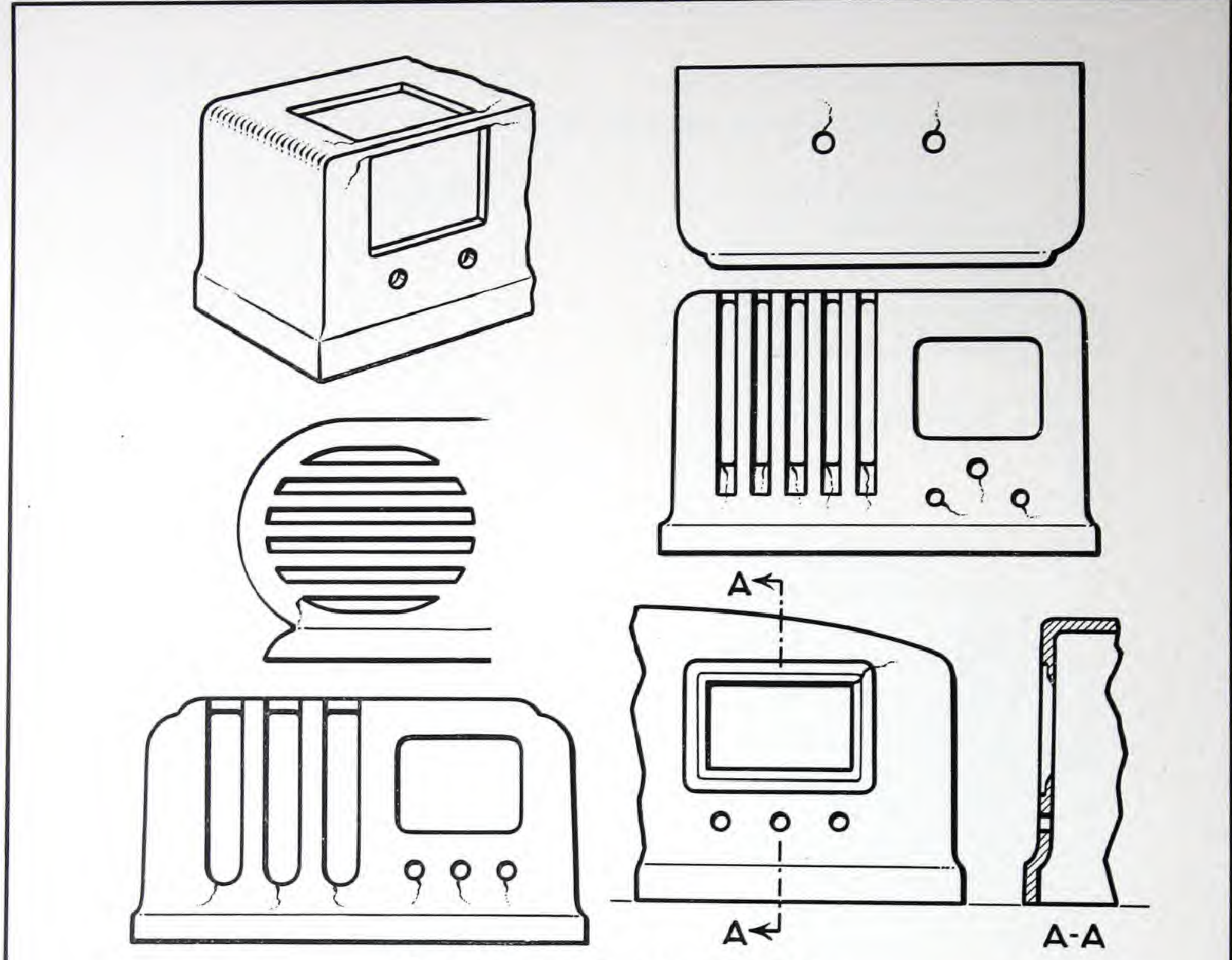
comparable to those used in drilling metal. Small drills are run at high speeds; large drills at low speeds.

Blind holes are drilled with a standard cutting angle, whereas through holes are usually made with a drill having a more tapered cutting edge in order to reduce chipping as the drill comes through the piece.

Variations in the density or hardness of the part are compensated for by altering the included angle of the cutting point of the drill. Hard materials are drilled using the standard angle of about 118°, and soft materials are best drilled using a more acute angle (90°–60°) on the drill.

If drilled holes are to be tapped, a drill two or three numbers larger than the size used in drilling steel should be used. A blind drilled hole should be tapped only 75% of its depth. And taps for this purpose should have the lead removed before they are used.

For drilling through holes in thin sections, slow helix or even straight fluted drills are advantageous.



Points where cracking may occur on aging.

Tapping is not recommended for holes above ⅛″ in diameter. The larger the tap the sooner it dulls and the more the thread will chip. Above this size use a brass insert. If the piece is to be reassembled many times, the molded insert is preferable.

Do not call for unnecessarily close tolerances.

In all cases place full confidence in your molder and treat him as a consulting engineer in whom you can confide. Let him know how your part will be used, what its life expectancy is to be, and the volume of items you will require. If the application for your part is new follow this procedure:

1. Obtain samples of the plastic you want to use, and test them under service conditions as closely approximating your conditions as possible.

2. Construct a model of the part with the advice of your molder or raw material supplier.

3. When model is acceptable, build a single cavity die to produce the actual part.

4. If this serves the purpose contemplated, construct the regular production die.

MATERIALS COMPARISON TABLE

MATERIAL	SPECIFIC GRAVITY	WEIGHT (Per Cu. In.)	TENSILE STRENGTH (Lbs. per Sq. Inch)
Beetle	1.45-1.50	0.85-0.89 oz.	5500-7000

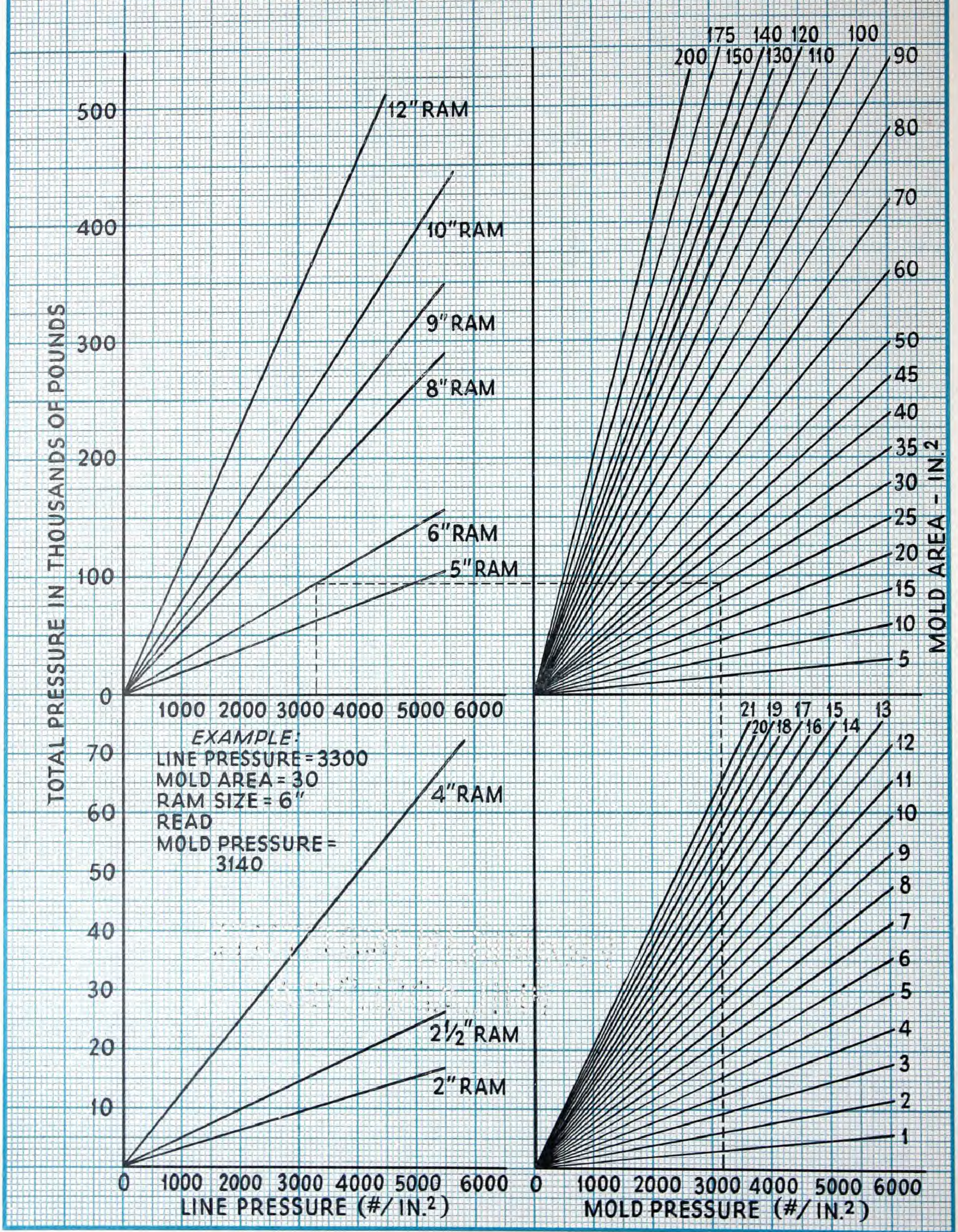
METALS

Aluminum	2.67	1.538 oz.	30000-40000
Brass (70-30)	8.40	4.838 oz.	45000-85000
Copper	8.853	5.099 oz.	60000-70000
Steel	7.854	4.524 oz.	80000-330000
Tin	7.35	4.234 oz.	4000-5000
Zinc	7.0	4.032 oz. (cast)	7000-13000

MISCELLANEOUS MATERIALS

Glass	2.6-3.7	1.498-2.131 oz.	Up to 13,000
Mica	2.9	1.670 oz.	15,000 shear lb. per sq. in.
Porcelain	2.4	1.382 oz.	3,000
Rubber, Hard (Commercial Grade)	1.15-1.4	0.6624-0.8064 oz.	4000-8000
Wood (Hard Maple)	0.68 (average)	0.3917 oz. (average)	26,000
(Soft—W. Pine)	0.45 (average)	0.2592 oz. (average)	17,300

HYDRAULIC PRESSURE RELATIONS



CAPACITIES OF HYDRAULIC RAMS IN TONS

Dia.	PRESSURE IN POUNDS PER SQUARE INCH																					Gal. per Inch	Gal. per Ft.	Area	Dia.
	300	500	600	750	1000	1200	1500	1800	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500	6000	6500	7000				
1	0.12	0.20	0.24	0.29	0.39	0.47	0.59	0.71	0.79	0.88	0.98	1.08	1.18	1.37	1.57	1.77	1.96	2.16	2.36	2.55	2.76	.003	.041	0.79	1
1½	0.27	0.44	0.53	0.66	0.88	1.06	1.33	1.59	1.77	1.99	2.21	2.43	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74	6.19	.008	.092	1.77	1½
2	0.47	0.79	0.94	1.18	1.57	1.88	2.36	2.83	3.14	3.53	3.93	4.32	4.71	5.50	6.28	7.07	7.85	8.64	9.42	10.2	11.0	.014	.163	3.14	2
2½	0.74	1.23	1.47	1.84	2.45	2.95	3.68	4.42	4.91	5.52	6.14	6.75	7.36	8.59	9.82	11.0	12.3	13.5	14.7	16.0	17.2	.023	.255	4.91	2½
3	1.06	1.77	2.12	2.65	3.53	4.24	5.30	6.36	7.07	7.95	8.84	9.72	10.6	12.4	14.1	15.9	17.7	19.4	21.2	23.0	24.7	.031	.367	7.07	3
3½	1.44	2.41	2.89	3.61	4.81	5.77	7.22	8.66	9.62	10.8	12.0	13.2	14.4	16.8	19.2	21.6	24.1	26.5	28.9	31.3	33.7	.042	.500	9.62	3½
4	1.88	3.14	3.77	4.71	6.28	7.54	9.42	11.3	12.6	14.1	15.7	17.3	18.8	22.0	25.1	28.3	31.4	34.6	37.7	40.8	44.0	.054	.653	12.6	4
4½	2.39	3.98	4.77	5.96	7.95	9.54	11.9	14.3	15.9	17.9	19.9	21.9	23.9	27.8	31.8	35.8	39.8	43.7	47.7	51.7	55.7	.069	.826	15.9	4½
5	2.95	4.91	5.89	7.36	9.82	11.8	14.7	17.7	19.6	22.1	24.5	27.0	29.5	34.3	39.3	44.2	49.1	54.0	58.9	63.8	68.7	.085	1.02	19.6	5
5½	3.56	5.94	7.13	8.91	11.9	14.3	17.8	21.4	23.8	26.7	29.7	32.7	35.6	41.6	47.5	53.5	59.4	65.3	71.3	77.2	83.2	.103	1.33	23.8	5½
6	4.24	7.07	8.48	10.6	14.1	17.0	21.2	25.4	28.3	31.8	35.3	38.9	42.4	49.5	56.5	63.6	70.7	77.8	84.8	91.9	99.0	.122	1.47	28.3	6
6½	4.98	8.30	9.96	12.4	16.6	19.9	24.9	29.9	33.2	37.3	41.5	45.6	49.8	58.1	66.4	74.7	83.0	91.3	99.6	108	116	.144	1.72	33.2	6½
7	5.77	9.62	11.5	14.4	19.2	23.1	28.9	34.6	38.5	43.3	48.1	52.9	57.7	67.3	77.0	86.6	96.2	106	115	125	135	.167	2.00	38.5	7
7½	6.63	11.0	13.3	16.6	22.1	26.5	33.1	39.8	44.2	49.7	55.2	60.7	66.3	77.3	88.4	99.4	110	121	133	144	155	.191	2.30	44.2	7½
8	7.54	12.6	15.1	18.8	25.1	30.2	37.7	45.3	50.3	56.5	62.8	69.1	75.4	88.0	101	113	126	138	151	163	176	.218	2.61	50.3	8
8½	8.51	14.2	17.0	21.3	28.4	34.0	42.6	51.1	56.7	63.8	70.9	78.0	85.1	99.3	113	128	142	156	170	184	199	.246	2.95	56.7	8½
9	9.54	15.9	19.1	23.9	31.8	38.2	47.7	57.3	63.6	71.6	79.5	87.5	95.4	111	127	143	159	175	191	207	223	.275	3.30	63.6	9
9½	10.6	17.7	21.3	26.6	35.4	42.5	53.2	63.8	70.9	79.7	88.6	97.5	106	124	142	159	177	195	213	230	248	.307	3.68	70.9	9½
10	11.8	19.6	23.6	29.5	39.3	47.1	58.9	70.7	78.5	88.4	98.2	108	118	137	157	177	196	216	236	255	276	.340	4.08	78.5	10
11	14.3	23.8	28.5	35.6	47.5	57.0	71.3	85.5	95.0	107	119	131	143	166	190	214	238	261	285	308	333	.411	4.94	95.0	11
12	17.0	28.3	33.9	42.4	56.5	67.9	84.8	102	113	127	141	156	170	198	226	254	283	311	339	368	396	.490	5.88	113	12
13	19.9	33.2	39.8	49.8	66.4	79.6	99.5	119	133	149	166	183	199	232	265	299	332	365	398	431	465	.575	6.90	133	13
14	23.1	38.5	46.2	57.7	77.0	92.4	115	139	154	173	192	212	231	269	308	346	385	423	462	500	539	.666	8.00	154	14
15	26.5	44.2	53.0	66.3	88.4	106	133	159	177	199	221	243	265	309	353	398	442	486	530	574	619	.765	9.18	177	15
16	30.2	50.3	60.3	75.4	101	121	151	181	201	226	251	276	302	352	402	452	503	553	603	653	704	.870	10.4	201	16
17	34.0	56.7	68.1	85.1	113	136	170	204	227	255	284	312	340	397	454	511	567	624	681	738	794	.983	11.8	227	17
18	38.2	63.6	76.3	95.4	127	153	191	229	254	286	318	350	382	445	509	573	636	700	763	827	891	1.10	13.2	254	18
19	42.5	70.9	85.1	106	142	170	213	252	284	319	354	390	425	497	567	638	709	780	851	921	992	1.23	14.7	284	19
20	47.1	78.5	94.2	118	157	188	236	283	314	353	393	432	471	550	628	707	785	864	942	1021	1100	1.36	16.3	314	20
21	52.0	86.6	104	130	173	208	260	312	346	390	433	476	520	606	693	779	866	952	1039	1126	1212	1.50	18.0	346	21
22	57.0	95.0	114	142	190	228	285	342	380	428	475	523	570	665	760	855	950	1045	1140	1235	1330	1.65	19.7	380	22
23	62.3	104	125	156	208	249	312	373	415	467	519	571	623	727	831	935	1039	1143	1246	1350	1454	1.80	21.6	415	23
24	67.9	113	136	170	226	271	339	407	452	509	565	622	679	792	905	1018	1131	1244	1357	1470	1583	1.96	23.5	452	24
25	73.6	123	147	184	245	295	368	442	491	552	614	675	736	859	982	1104	1227	1350	1473	1595	1718	2.13	25.5	491	25
26	79.6	133	159	199	265	319	398	478	531	597	664	730	796	929	1062	1195	1327	1460	1593	1726	1858	2.30	27.6	531	26
27	85.9	143	172	215	286	344	429	515	573	644	716	787	859	1002	1145	1288	1431	1575	1718	1861	2004	2.48	29.7	573	27
28	92.4	154	185	231	308	369	462	554	616	693	770	847	924	1078	1232	1385	1539	1693	1847	2001	2155	2.67	32.0	616	28
29	99.1	165	198	248	330	396	495	594	661	743	826	908	991	1156	1321	1486	1651	1816	1982	2147	2312	2.86	34.3	661	29
30	106	177	212	265	353	424	530	636	707	795	884	972	1060	1237	1414	1590	1767	1944	2121	2297	2474	3.06	36.7	707	30
31	113	189	226	283	377	453	566	678	755	849	943	1038	1132	1321	1510	1698	1887	2076	2264	2453	2642	3.27	39.2	755	31
32	121	201	241	302	402	483	603	724	804	905	1005	1106	1206	1408	1608	1810	2011	2212	2413	2614	2816	3.48	41.8	804	32
33	128	214	257	321	428	513	641	770	855	962	1069	1176	1283	1497	1711	1924	2138	2352	2566	2780	2994	3.70	44.4	855	33
34	136	227	272	340	454	545	681	817	908	1021	1135	1248	1362	1589	1816	2043	2270	2497	2724	2951	3178	3.94	47.2	908	34
35	144	241	289	361	481	577	722	866	962	1082	1203	1323	1443	1684	1924	2165	2405	2646	2886	3127	3367	4.17	50.0	962	35
36	153	254	305	382	509	611	763	916	1018	1145	1272	1400	1527	1781	2036	2290	2545	2799	3054	3308	3563	4.41	52.9	1018	36
37	161	269	323	403	538	645	806	968	1075	1210	1344	1478	1613	1882	3150	2419	2688	2957	3226	3494	3763	4.6[illegible]	55.9	1075	37
38	170	284	340	425	567	680	851	1021	1134	1276	1418	1559	1701	1985	2268	2552	2835	3119	3402	3686	3969	4.91	58.9	1134	38
39	179	299	358	448	597	717	894	1075	1195	1344	1493	1643	1792	2091	2389	2688	2986	3285	3584	3882	4181	5.17	62.1	1195	39
40	188	314	377	471	628	754	942	1131	1257	1414	1572	1728	1885	2199	2513	2827	3142	3456	3770	4084	4398	5.44	65.3	1257	40
41	198	330	396	495	660	792	990	1188	1320	1485	1650	1815	1980	2310	2641	2971	3301	3631	3961	4291	4621	5.72	68.6	1320	41
42	208	346	416	520	693	831	1039	1247	1385	1559	1732	1905	2078	2425	2771	3117	3464	3810	4156	4503	4849	6.00	72.0	1385	42
43	218	363	436	542	726	871	1089	1307	1452	1634	1815	1997	2178	2541	2904	3267	3631	3994	4357	4720	5083	6.29	75.4	1452	43
44	228	380	456	570	760	912	1140	1368	1521	1711	1901	2091	2281	2661	3041	3421	3801	4181	4562	4942	5322	6.58	79.0	1521	44
45	239	398	477	596	795	954	1193	1431	1590	1789	1988	2187	2386	2783	3181	3578	3976	4374	4771	5169	5567	6.89	82.6	1590	45
46	249	415	499	623	831	997	1246	1496	1662	1870	2077	2285	2493	2908	3324	3739	4155	4570	4986	5401	5817	7.19	86.3	1662	46
47	260	434	520	651	867	1041	1301	1561	1735	1952	2169	2386	2602	3036	3470	3904	4337	4771	5205	5639	6072	7.51	90.1	1735	47
48	271	452	543	679	905	1086	1357	1629	1810	2036	2262	2488	2714	3167	3619	4072	4524	4976	5429	5881	6333	7.83	94.0	1810	48
49	283	471	566	707	943	1131	1414	1697	1886	2121	2357	2593	2829	3300	3771	4243	4714	5186	5657	6129	6600	8.16	98.0	1886	49
50	295	491	589	736	982	1178	1473	1767	1963	2209	2454	2700	2945	3436	3927	4418	4909	5400	5890	6381	6872	8.50	102	1963	50
52	319	531	637	796	1060	1270	1590	1910	2120	2390	2650	2920	3190	3720	4250	4780	5310	5840	6370	6900	7430	9.19	110	2124	52
54	344	573	687	859	1150	1370	1720	2060	2290	2580	2860	3150	3440	4010	4580	5150	5730	6300	6870	7440	8020	9.91	119	2290	54
56	369	616	739	924	1230	1480	1850	2220	2460	2770	3080	3390	3690	4310	4930	5540	6160	6770	7390	8000	8620	10.7	128	2463	56
58	396	660	793	991	1320	1590	1980	2380	2640	2970	3300	3630	3960	4620	5280	5940	6600	7270	7930	8590	9250	11.4	137	2642	58
60	424	707	848	1060	1410	1700	2120	2540	2830	3180	3530	3890	4240	4950	5650	6360	7070	7780	8480	9190	9900	12.2	147	2827	60
	.175	.292	.350	.438	.583	.700	.875	1.05	1.17	1.31	1.46	1.60	1.75	2.04	2.33	2.62	2.92	3.21	3.50	3.79	4.08	H. P. per gal. per min.			

CONVERSION OF VOLUMES OR CUBIC MEASURE

	Cubic Inches to Cubic Centimeters	Cubic Centimeters to Cubic Inches	Cubic Feet to Cubic Meters	Cubic Meters to Cubic Feet	Cubic Yards to Cubic Meters	Cubic Meters to Cubic Yards	Gallons to Cubic Feet	Cubic Feet to Gallons
1	16.39	0.06102	0.02832	35.31	0.7646	1.308	0.1337	7.481
2	32.77	0.1220	0.05663	70.63	1.529	2.616	0.2674	14.96
3	49.16	0.1831	0.08495	105.9	2.294	3.924	0.4011	22.44
4	65.55	0.2441	0.1133	141.3	3.058	5.232	0.5348	29.92
5	81.94	0.3051	0.1416	176.6	3.823	6.540	0.6685	37.41
6	98.32	0.3661	0.1699	211.9	4.587	7.848	0.8022	44.89
7	114.7	0.4272	0.1982	247.2	5.352	9.156	0.9359	52.36
8	131.1	0.4882	0.2265	282.5	6.116	10.46	1.070	59.85
9	147.5	0.5492	0.2549	317.8	6.881	11.77	1.203	67.33

DECIMAL EQUIVALENTS OF FRACTIONS OF ONE INCH

1/64	.015 625	17/64	.265 625	33/64	.515 625	49/64	.765 625
1/32	.031 250	9/32	.281 250	17/32	.531 250	25/32	.781 250
3/64	.046 875	19/64	.296 875	35/64	.546 875	51/64	.796 875
1/16	.062 500	5/16	.312 500	9/16	.562 500	13/16	.812 500
5/64	.078 125	21/64	.328 125	37/64	.578 125	53/64	.828 125
3/32	.093 750	11/32	.343 750	19/32	.593 750	27/32	.843 750
7/64	.109 375	23/64	.359 375	39/64	.609 375	55/64	.859 375
1/8	.125 000	3/8	.375 000	5/8	.625 000	7/8	.875 000
9/64	.140 625	25/64	.390 625	41/64	.640 625	57/64	.890 625
5/32	.156 250	13/32	.406 250	21/32	.656 250	29/32	.906 250
11/64	.171 875	27/64	.421 875	43/64	.671 875	59/64	.921 875
3/16	.187 500	7/16	.437 500	11/16	.687 500	15/16	.937 500
13/64	.203 125	29/64	.453 125	45/64	.703 125	61/64	.953 125
7/32	.218 750	15/32	.468 750	23/32	.718 750	31/32	.968 750
15/64	.234 375	31/64	.484 375	47/64	.734 375	63/64	.984 375
1/4	.250 000	1/2	.500 000	3/4	.750 000	1	1.000 000

TAP AND DRILL SIZES

Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.	Size of Tap, No.	Size of Drill, No.
2 x 48	50	7 x 32	30	13 x 20	15	18 x 20	A
2 x 56	49	8 x 24	30	13 x 22	15	19 x 16	B
2 x 64	48	8 x 30	30	13 x 24	13	19 x 18	C
3 x 40	47	8 x 32	29	14 x 20	13	19 x 20	D
3 x 48	45	9 x 24	29	14 x 22	11	20 x 16	D
3 x 56	44	9 x 28	28	14 x 24	9	20 x 18	F
4 x 32	43	9 x 30	27	15 x 18	10	20 x 20	H
4 x 36	42	9 x 32	25	15 x 20	8	22 x 16	J
4 x 40	41	10 x 24	25	15 x 22	6	22 x 18	L
5 x 30	40	10 x 30	22	15 x 24	5	24 x 14	M
5 x 32	40	10 x 32	21	16 x 16	7	24 x 16	N
5 x 36	38	11 x 24	21	16 x 18	6	24 x 18	O
5 x 40	37	11 x 28	17	16 x 20	5	26 x 14	O
6 x 30	35	11 x 30	17	17 x 16	6	26 x 16	P
6 x 32	35	12 x 20	19	17 x 18	2	28 x 14	R
6 x 36	33	12 x 22	17	17 x 20	2	28 x 16	S
6 x 40	32	12 x 24	17	18 x 16	2	30 x 14	U
7 x 28	32	12 x 28	15	18 x 18	1	30 x 16	V
7 x 30	31						

TEMPERATURE CONVERSION TABLES

NOTE:—The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, use the column on the right.

C.		F.	C.		F.	C.		F.	C.		F.	C.		F.
—17.8	**0**	32	15.0	**59**	138.2	132	**270**	518	454	**850**	1562	777	**1430**	2606
—17.2	**1**	33.8	15.6	**60**	140.0	138	**280**	536	460	**860**	1580	782	**1440**	2624
—16.7	**2**	35.6	16.1	**61**	141.8	143	**290**	554	466	**870**	1598	788	**1450**	2642
—16.1	**3**	37.4	16.7	**62**	143.6	149	**300**	572	471	**880**	1616	793	**1460**	2660
—15.6	**4**	39.2	17.2	**63**	145.4	154	**310**	590	477	**890**	1634	799	**1470**	2678
—15.0	**5**	41.0	17.8	**64**	147.2	160	**320**	608	482	**900**	1652	804	**1480**	2696
—14.4	**6**	42.8	18.3	**65**	149.0	166	**330**	626	488	**910**	1670	810	**1490**	2714
—13.9	**7**	44.6	18.9	**66**	150.8	171	**340**	644	493	**920**	1688	816	**1500**	2732
—13.3	**8**	46.4	19.4	**67**	152.6	177	**350**	662	499	**930**	1706	821	**1510**	2750
—12.8	**9**	48.2	20.0	**68**	154.4	182	**360**	680	504	**940**	1724	827	**1520**	2768
—12.2	**10**	50.0	20.6	**69**	156.2	188	**370**	698	510	**950**	1742	832	**1530**	2786
—11.7	**11**	51.8	21.1	**70**	158.0	193	**380**	716	516	**960**	1760	838	**1540**	2804
—11.1	**12**	53.6	21.7	**71**	159.8	199	**390**	734	521	**970**	1778	843	**1550**	2822
—10.6	**13**	55.4	22.2	**72**	161.6	204	**400**	752	527	**980**	1796	849	**1560**	2840
—10.0	**14**	57.2	22.8	**73**	163.4	210	**410**	770	532	**990**	1814	854	**1570**	2858
— 9.44	**15**	59.0	23.3	**74**	165.2	216	**420**	788	538	**1000**	1832	860	**1580**	2876
— 8.89	**16**	60.8	23.9	**75**	167.0	221	**430**	806	543	**1010**	1850	866	**1590**	2894
— 8.33	**17**	62.6	24.4	**76**	168.8	227	**440**	824	549	**1020**	1868	871	**1600**	2912
— 7.78	**18**	64.4	25.0	**77**	170.6	232	**450**	842	554	**1030**	1886	877	**1610**	2930
— 7.22	**19**	66.2	25.6	**78**	172.4	238	**460**	860	560	**1040**	1904	882	**1620**	2948
— 6.67	**20**	68.0	26.1	**79**	174.2	243	**470**	878	566	**1050**	1922	888	**1630**	2966
— 6.11	**21**	69.8	26.7	**80**	176.0	249	**480**	896	571	**1060**	1940	893	**1640**	2984
— 5.56	**22**	71.6	27.2	**81**	177.8	254	**490**	914	577	**1070**	1958	899	**1650**	3002
— 5.00	**23**	73.4	27.8	**82**	179.6	260	**500**	932	582	**1080**	1976	904	**1660**	3020
— 4.44	**24**	75.2	28.3	**83**	181.4	266	**510**	950	588	**1090**	1994	910	**1670**	3038
— 3.89	**25**	77.0	28.9	**84**	183.2	271	**520**	968	593	**1100**	2012	916	**1680**	3056
— 3.33	**26**	78.8	29.4	**85**	185.0	277	**530**	986	599	**1110**	2030	921	**1690**	3074
— 2.78	**27**	80.6	30.0	**86**	186.8	282	**540**	1004	604	**1120**	2048	927	**1700**	3092
— 2.22	**28**	82.4	30.6	**87**	188.6	288	**550**	1022	610	**1130**	2066	932	**1710**	3110
— 1.67	**29**	84.2	31.1	**88**	190.4	293	**560**	1040	616	**1140**	2084	938	**1720**	3128
— 1.11	**30**	86.0	31.7	**89**	192.2	299	**570**	1058	621	**1150**	2102	943	**1730**	3146
— 0.56	**31**	87.8	32.2	**90**	194.0	304	**580**	1076	627	**1160**	2120	949	**1740**	3164
0	**32**	89.6	32.8	**91**	195.8	310	**590**	1094	632	**1170**	2138	954	**1750**	3182
0.56	**33**	91.4	33.3	**92**	197.6	316	**600**	1112	638	**1180**	2156	960	**1760**	3200
1.11	**34**	93.2	33.9	**93**	199.4	321	**610**	1130	643	**1190**	2174	966	**1770**	3218
1.67	**35**	95.0	34.4	**94**	201.2	327	**620**	1148	649	**1200**	2192	971	**1780**	3236
2.22	**36**	96.8	35.0	**95**	203.0	332	**630**	1166	654	**1210**	2210	977	**1790**	3254
2.78	**37**	98.6	35.6	**96**	204.8	338	**640**	1184	660	**1220**	2228	982	**1800**	3272
3.33	**38**	100.4	36.1	**97**	206.6	343	**650**	1202	666	**1230**	2246	988	**1810**	3290
3.89	**39**	102.2	36.7	**98**	208.4	349	**660**	1220	671	**1240**	2264	993	**1820**	3308
4.44	**40**	104.0	37.2	**99**	210.2	354	**670**	1238	677	**1250**	2282	999	**1830**	3326
5.00	**41**	105.8	37.8	**100**	212.0	360	**680**	1256	682	**1260**	2300	1004	**1840**	3344
5.56	**42**	107.6	43	**110**	230	366	**690**	1274	688	**1270**	2318	1010	**1850**	3362
6.11	**43**	109.4	49	**120**	248	371	**700**	1292	693	**1280**	2336	1016	**1860**	3380
6.67	**44**	111.2	54	**130**	266	377	**710**	1310	699	**1290**	2354	1021	**1870**	3398
7.22	**45**	113.0	60	**140**	284	382	**720**	1328	704	**1300**	2372	1027	**1880**	3416
7.78	**46**	114.8	66	**150**	302	388	**730**	1346	710	**1310**	2390	1032	**1890**	3434
8.33	**47**	116.6	71	**160**	320	393	**740**	1364	716	**1320**	2408	1038	**1900**	3452
8.89	**48**	118.4	77	**170**	338	399	**750**	1382	721	**1330**	2426	1043	**1910**	3470
9.44	**49**	120.2	82	**180**	356	404	**760**	1400	727	**1340**	2444	1049	**1920**	3488
10.0	**50**	122.0	88	**190**	374	410	**770**	1418	732	**1350**	2462	1054	**1930**	3506
10.6	**51**	123.8	93	**200**	392	416	**780**	1436	738	**1360**	2480	1060	**1940**	3524
11.1	**52**	125.6	99	**210**	410	421	**790**	1454	743	**1370**	2498	1066	**1950**	3542
11.7	**53**	127.4	100	**212**	413	427	**800**	1472	749	**1380**	2516	1071	**1960**	3560
12.2	**54**	129.2	104	**220**	428	432	**810**	1490	754	**1390**	2534	1077	**1970**	3578
12.8	**55**	131.0	110	**230**	446	438	**820**	1508	760	**1400**	2552	1082	**1980**	3596
13.3	**56**	132.8	116	**240**	464	443	**830**	1526	766	**1410**	2570	1088	**1990**	3614
13.9	**57**	134.6	121	**250**	482	449	**840**	1544	771	**1420**	2588	1093	**2000**	3632
14.4	**58**	136.4	127	**260**	500									

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